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FEDERAL AVIATION ADMINISTRATION WASHINGTON DC  
THE FAA PLANS AND PROGRAMS FOR THE FUTURE AIRPORT AND AIR TRAFF--ETC(U)  
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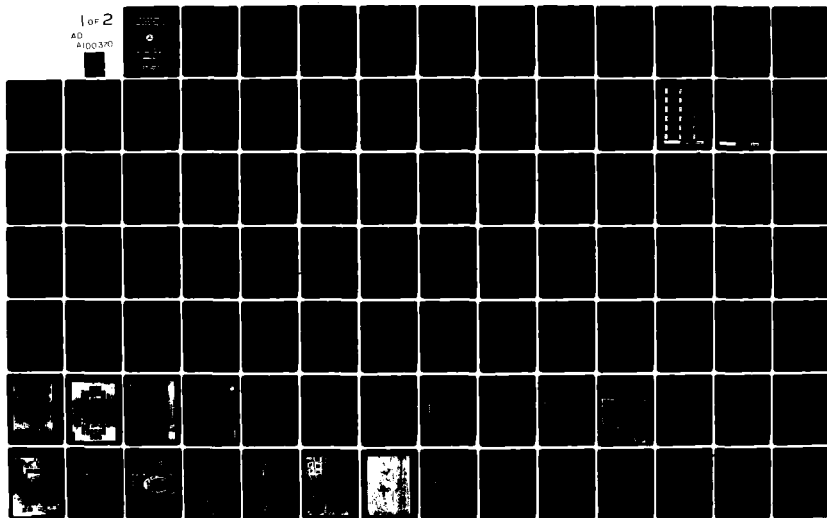
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**THE FAA PLANS AND PROGRAMS  
FOR THE FUTURE  
AIRPORT AND AIR TRAFFIC CONTROL SYSTEM .**



12/83

**Presentations for the  
Office of Technology Assessment Seminar**

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Prepared by

**U. S. DEPARTMENT OF TRANSPORTATION  
FEDERAL AVIATION ADMINISTRATION  
Washington, D. C. 20590**

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REPLACEMENT COPY

1. Report No.	2. Government Accession No. <i>AD-ALCC 370</i>	3. Recipient's Catalog No.
4. Title and Subtitle The FAA Plans and Programs for the Future Airport and Air Traffic Control System	5. Report Date November 1980	6. Performing Organization or Code AEM
7. Author(s)	8. Performing Organization Report No.	
9. Performing Organization Name and Address Federal Aviation Administration 800 Independence Ave., S.W. Washington, D.C. 20591	10. Work Unit No. (if applicable)	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Washington, D.C. 20591	13. Type of Report and Period Covered	14. Sponsoring Agency Code
15. Supplementary Notes		
16. Abstract		
17. Key Words	18. Distribution Statement Document is available to the public through the National Technical Informa- tion Service, Springfield, Virginia 22161	
19. Security Classification of this report Unclassified	20. Security Classification of this page Unclassified	21. Number of Pages 100

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INTRODUCTION -- FAA'S ROLE IN PROVIDING  
A SAFE AND EFFICIENT SYSTEM

by  
Neal A. Blake  
Deputy Associate Administrator  
for Engineering and Development

I am pleased to be here this morning to introduce a very full day of briefings at this OTA Seminar on the Airport and Air Traffic Control System. We will attempt to respond specifically to the wishes of the Advisory Panel and the OTA staff in presenting the information you asked for.

- o We will begin with two briefings on "Traffic Forecasts on Aviation Activity, 1981-1982" and "Airport and Airway System Capacity and Delay Overview," to be given by Mr. Harvey Safeer, Director, Office of Aviation Policy and Plans.
- o Next will be a description of "Today's ATC System--Problems and Need for Change," by Mr. Raymond Van Vuren, Director, Air Traffic Service.
- o Next will be briefings on the system of tomorrow, including "An Overview of the FAA Engineering and Development Program," to be presented by Mr. Robert Wedan, Director, Systems Research and Development Service. Then follows a description of the "Scenario for the Future System," "The Roadmap to the System of the Future," and "The Impact of Alternative Approaches in Air Traffic Control System Evolution," to be given by Mr. Siegbert Poritzky, Director, Office of Systems Engineering Management.
- o After lunch, Mr. Poritzky will continue with a briefing on bottom line findings from FAA's extensive airport capacity and delay activities.
- o Mr. Martin Pozesky, Deputy Director, Systems Research and Development Service, will describe several of our near-term research and development activities for system improvement.
- o He will be followed by a briefing on several of FAA's longer term system improvement activities, by Dr. Edmund Koenke, Acting Deputy Director, Office of Systems Engineering Management.
- o Mr. Safeer will then return to discuss "Non-Technological Alternatives for Balancing Airport/Airspace Supply and Demand," and
- o I will close the formal presentations with a brief wrap-up.

Your staff has laid on a very extensive program, and we will need your help to get through it quickly and effectively.

Before we start, I would like to spend a moment or two discussing FAA's role in providing a safe and efficient system, although I know that each of you here is very much familiar with FAA's roles and activities.

The basic tasks that FAA performs are:

- o The management and operation of the National Airspace System;
- o The issuance and enforcement of safety rules and regulations;
- o The certification of airmen, aircraft, aircraft components, air agencies and airports; and
- o The conduct of aviation safety-related research and development.

The dimensions of the system are large. At the end of Calendar Year 1979 there were some 800,000 active FAA certificated pilots, including more than 200,000 student pilots. Among non-pilot airmen with FAA certificates are 229,000 mechanics, nearly 26,000 control tower operators, and about 33,000 flight engineers. There are some 2,660 air carrier aircraft; 202,000 general aviation aircraft; some 2,500 pilot schools; 134 mechanic schools; 2,750 repair stations in the United States, and 107 overseas.

FAA employs upwards of 56,000 people, including over 16,000 air traffic controllers. There are 431 air traffic control towers, 25 control centers, and 319 Flight Service Stations. On the equipment side, there are about 10,000 navigational aids operated to define the 351,000 miles of the Federal Airway System. The airport network consists of nearly 15,000 landing fields, including 4,761 publicly-owned airports, of which 736 serve both scheduled carriers and general aviation aircraft.

Mr. Safeer will talk to you in some detail about our forecasts. He will show that the U.S. aviation industry continues to grow on almost all fronts. Yet, there are problems ahead. A few days ago Administrator Bond said:

"...Despite the apparent strength of our industry and the outlook for business ahead, aviation is at a crossroad that threatens disaster, born perhaps because of the increasing acceptance and dependence of people everywhere on air transportation, and fueled, certainly, by increasing economic pressures on industry and government. The well-being of the entire industry is threatened."

"The...aviation community has become unhealthily fractious. In pursuit of narrow interests, too many of us ignore the general health of aviation. Unless we can get together, and soon, on the issues confronting us; unless we manifest a working belief that our professional intentions are truly mutual--one with another's--we may soon find ourselves squarely in the midst of irrevocable restraints that may irreparably constrain aviation's growth."

In briefing you today, you will see that we are working on a number of improvements and remedies. You will also see that there is a clear requirement for major capital investment in the system during this and the next decade. The funding levels for these investments which FAA has proposed represent a growth budget. At the same time, we all know that we are operating in an environment of fiscal restraints at all levels of government. The critical question is whether the Federal budget for aviation capital investment can grow fast enough to accommodate the dimensions we foresee.

A question undoubtedly before you is whether we know where we are going and what we are doing to meet the need. Messrs. Van Vuren and Safeer will tell you of the current system, the problems in it, and the economic and policy issues confronting the community. We will describe to you something of the Engineering and Development program intended to lead us to the Year 2000 in a rational and progressive fashion.

Much of the aviation community is aware of what we are doing through long-time exposure and exchanges of view which occur on an almost continuous basis. The effort we called "New Engineering and Development Initiatives--Policy and Technology Choices" was an attempt to lay out before the entire community what we saw as problems and solutions. We asked for and received guidance on many of the same issues you are confronting. The people involved in this process spent literally months bringing themselves up-to-date on what we were doing, and developing thoughtful recommendations which we are taking seriously indeed. In the bottom line, the New E&D Initiatives results represent strong and informed support for our Engineering and Development program and recommendations for strengthening it in a number of areas. We are trying to do so within the very real limitations on available resources.

I mentioned earlier that there would be a discussion of alternative paths to the system of tomorrow, and questions about those alternative paths have already been raised in the staff assessments as they were during the New Engineering and Development Initiatives effort and often before. We are well aware that there are alternatives and have been studying a number of them. Such issues as the balance of responsibility between the pilot and the control system, the future air traffic control surveillance system, the number of air traffic control centers, the future navigation system, the acceptable levels of automation, and others, all represent forks in the road on which decisions will need to be made. But the decisions will have to be made in such a way that one unresolved issue doesn't hold up the train. We will be discussing these issues in more detail later in our presentations.

The briefings in this seminar will give you an idea of the scope of our work and will, we hope, place you in a better position to make meaningful and thoughtful assessments of that need.

## FAA FORECASTS OF AVIATION ACTIVITY 1981 - 1992

by  
Harvey B. Safeer  
Director, Office of Aviation  
Policy and Plans

Forecasting is still as much an art as it is a science. There are no models or sets of models, however, sophisticated, that can "predict" future socioeconomic events. Most models of socioeconomic events merely state what we expect to happen if certain other events take place, the so-called exogenous variables, and if the relationship between the exogenous variables and what we are trying to forecast is as we have postulated it to be.

Forecasts of aviation activity are based upon other forecasts of general economic activity and relationships between what we expect to happen in the general economy and how these events will affect aviation. Thus, it is important to discuss not only the results of our forecasting efforts, but also the assumptions which we have either accepted, based upon the work of others, or those which we have either accepted, based upon the work of others, or those which we have made ourselves.

The key structural assumption which FAA has made with respect to the air transportation industry is that the basic relationship between the Federal Government and the industry will continue to be one of economic deregulation.

Based upon the Wharton long-term industry and economic forecasting model, FAA is using the following economic assumptions for the period 1980-1992:

1. Real gross national product is forecast to grow at an annual compound rate of 2.7 percent;
2. Employment is expected to grow at an annual compound rate of 1.3 percent;
3. Consumer price index is expected to rise some 11.7 percent in 1981, but by 1992, the rate of increase is expected to slowdown to 7.3 percent, with a compound annual rate of growth of 8.2 percent;
4. Real disposable personal income is expected to grow at a compound annual rate of 2.8 percent;
5. Fuel prices, based on the Wharton projection of the oil and gas deflation, are forecast to grow by 225 percent between 1980 and 1992. The forecast assumes, however, that fuel will be available for aviation; and
6. The unemployment rate is forecast to peak in 1981, and then decline to 5.0 percent by 1992.

In addition to these general economic assumptions, FAA has made a series of assumptions specific to aviation:

1. General aviation fuel costs will increase at an average annual rate of 10.4 percent;
2. The average annual fixed cost of owning and operating a general aviation aircraft will increase at an annual rate of about 6 percent;
3. The overall certificated air carrier average passenger trip length is expected to grow at the historical rate of 3 miles per year; and
4. Average seats per aircraft are expected to increase about 4 seats per year.

Two additional assumptions are: Load factors are expected to increase from about 61 percent in 1980 to 63 percent in 1984 and beyond, and revenue per passenger mile will increase in current dollars about 5 percent per year, but will decrease in constant dollars from the current 4.5 cents to 3.7 cents.

A change in any of these assumptions will, of course, affect the forecasts. Thus, FAA has continued the practice of developing a set of forecasts based upon alternative future scenarios. When you read the descriptions of these alternative scenarios, don't be put off by the postulated events that lead to the alternative assumptions. Just remember that what seemed to be far out and improbable to some in the early 1960's--deregulation, high fuel prices--are facts of life today. The important use of these scenarios is to postulate the possible changes in the exogenous variables and, in turn, to see how these changes impact our forecast of aviation activity.

The key forecasts which are expected to affect FAA policy and investment decision which must be made in the next few years are summarized below.

The air carrier industry is still undergoing a period of adjustment, not only to deregulation but also to higher fuel prices, environmental regulations, changing relationships within the industry and the introduction of new equipment. The jet age is slightly more than 20 years old and we will be seeing the third generation of new aircraft entering the fleet.

General aviation is also experiencing more subtle, but nevertheless critical change. In addition to having to cope with higher fuel prices and other costs, general aviation is being called upon to serve an increasing role in providing transportation which is essential to economic growth and development.

Domestic air carrier revenue passenger enplanements are expected to resume their growth in 1981 concurrent with recovery from the current recession. Over the 12-year period, we expect domestic revenue passenger enplanements to grow by an average 4.3 percent per year, while revenue passenger miles are expected to grow by some 4.8 percent per year.

Commuter carrier are expected to sustain a higher average annual growth rate, particularly as new equipment enters the fleet over the next few years.

We expect the general aviation fleet and total hours flown to increase at modest rates over the next 12 years. These growth rates, however, tend to mask the expected growth in the use of higher performance, better equipped, multi-engine aircraft which are entering the fleet at a rate which is double that of single engine aircraft.

Given these general forecasts of aviation activity, we expect a moderate rate of growth in FAA workload over the next 12 years, on the order of 3 percent per year for tower and center activities, approximately 4 percent for flight service station activities.

Total operations at airports with FAA traffic control service are forecast to increase by 43 percent between 1980 and 1992. However, this expected increase is only part of the story. We expect to see a continuation of the trend toward increased participation in the system of air taxis (including commuters) and general aviation itinerant flying. Thus, air carrier operations are expected to increase by only 21 percent over this time period while air taxi and general aviation itinerant operations are expected to grow by 98 percent and 49 percent respectively. General aviation local operations are forecast to grow by 39 percent.

The net effect of these differential growth rates is a redistribution in the mix of operations in the system. This shift in the mix of aircraft types using towered airports has its implications for the operation of the air traffic, the greater the problems associated with local flow control management. See Figure 1.

Instrument operations at towered airports are expected to increase at a slightly faster rate than total operations. This represents a continuation of the trend toward more sophisticated equipage of general aviation aircraft and their increased use for business and commercial purposes, as well as the effect of additional TCA's and TRSA's.

This trend is also reflected in the number of IFR aircraft handled by our air route traffic control centers. While total activity is expected to increase by 46 percent, air carrier aircraft handled are expected to increase by only 22 percent. Air taxi (commuter) and general aviation aircraft handled are expected to increase by 124 percent and 86 percent respectively. Once again, these differential growth rates will result in a redistribution of the relative share of the workload. By 1992, the centers will be handling almost as many general aviation aircraft as air carrier aircraft. See Figure 2.

As I indicated earlier, these forecasts are based upon a set of assumptions and forecasts of general economic activity. We also generated a series of forecasts based upon alternative sets of assumptions. While you can read the details of the scenarios and the resultant forecasts in the report, I think that it is important to focus on the implications of these alternative forecasts for 1992. Two of the scenarios, "Economic Expansion" and "Energy Conservation" tend to bracket the baseline forecast. In fact, if you look at the numbers carefully, you will observe that the general trend of the baseline forecast is closer to the "Energy Conservation" scenario. The general trend for the baseline and these first two alternative scenarios, is however, economic growth and concurrent aviation growth, albeit at differing rates. It is only under the third alternative scenario, "Stagflation," where we see a significant departure from a growth trend. See Figure 3.

The implications are significant. If we truly believe that our economy is going to grow at all over the next decade, we must accept the logical extension of that belief, which is that aviation will grow. To not accept the strong interdependence between the economy and aviation's future is to assume that the very structure of our air transportation system will change over the next 12 years. I do not foresee any technological, social, or economic changes which will be strong enough, in and of themselves, to either change these relationships significantly or reverse the long-term trends which we are forecasting. There may be cyclical perturbations about this trend, such as the recessions of 1975 and 1980, but so long as we continue to provide an adequate infrastructure for the air transportation system, the trend for all types of aviation activity is growth.

In conclusion, let me restate my initial premise: forecasting is at best an inexact science. Over the long-term, we can generate probable trends and identify both the forces underlying those trends and the forces which can cause deviations. If we can agree that the trends have been correctly identified, then we have developed a mutual framework for future planning and policy development.

FIGURE 1

# *Distribution of Operations at Airports With FAA Traffic Control Service*

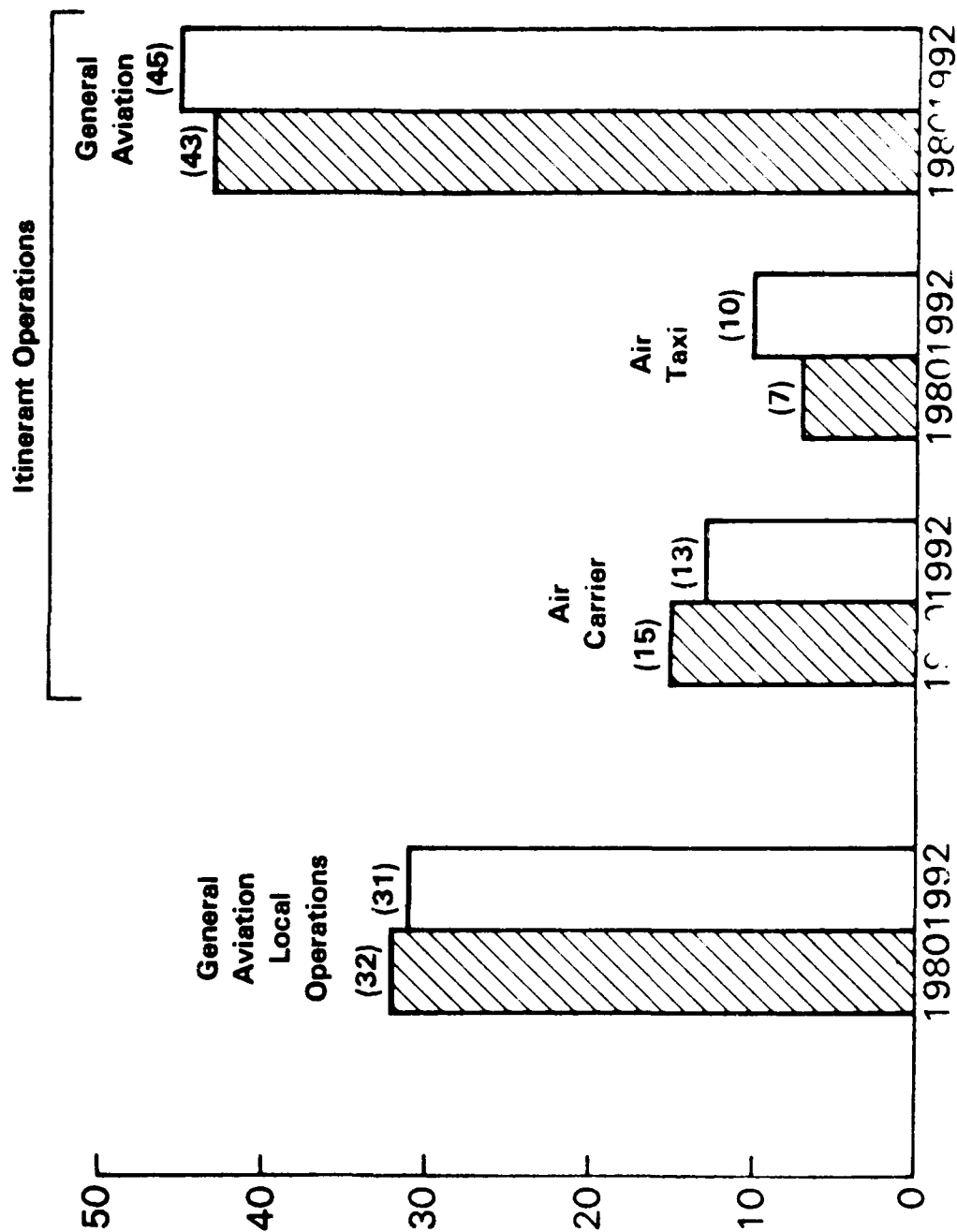
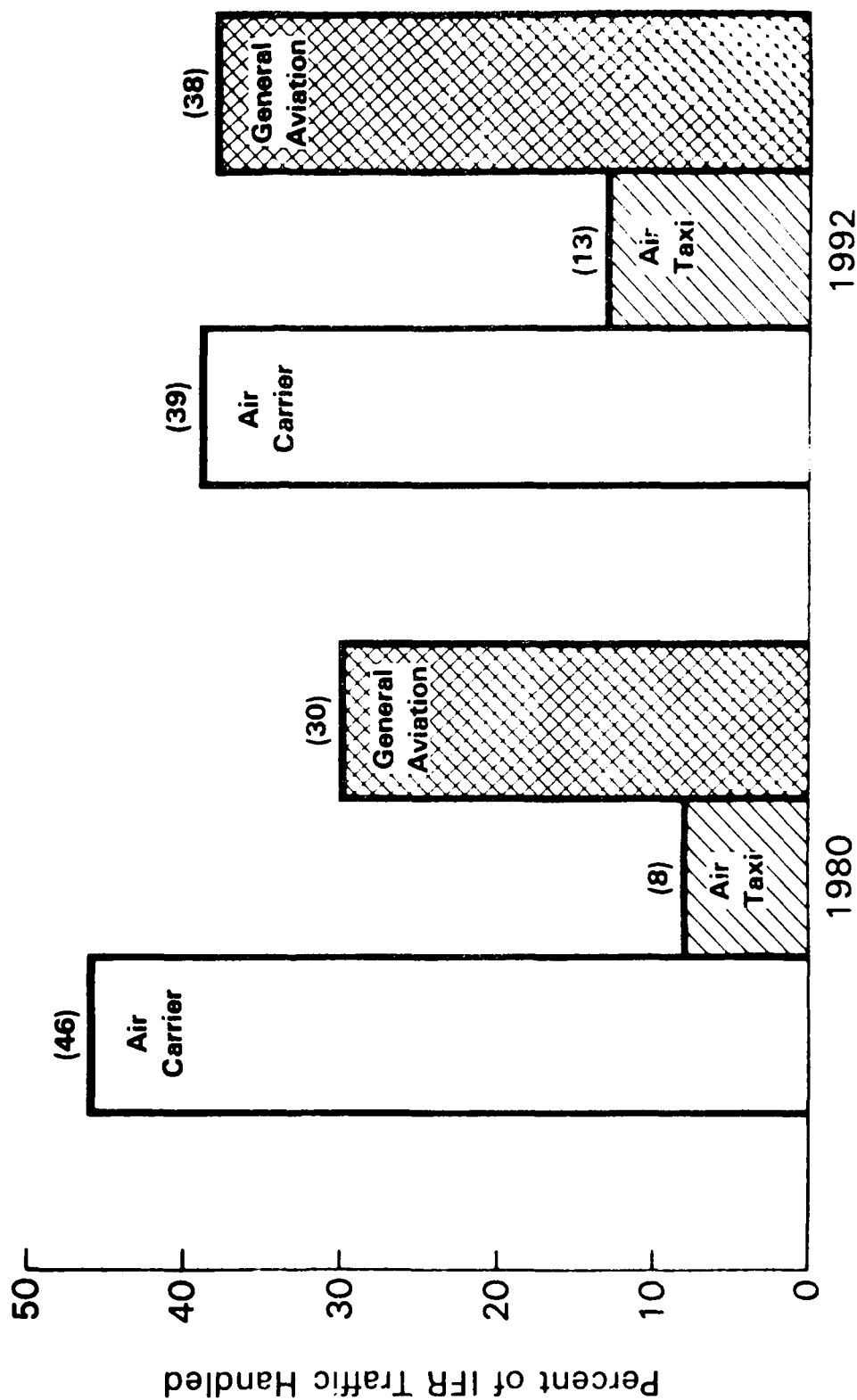




FIGURE 2

# *Distribution of IFR Traffic Handled by FAA Air Route Traffic Control Centers*



# ***Forecasts of FAA Workload Measures — Baseline and Alternative Scenarios***

FAA Workload (Millions)	FY 1992 Forecast			
	FY 1980 Base	Economic Expansion	Baseline	Energy Conservation Stagflation
Total Tower Operations	68.6	116.8	98.4	83.5
Total Instrument Operations	38.7	79.5	56.6	59.3
IFR Aircraft Handled	30.1	58.8	44.0	42.0
Flight Services	65.4	120.4	103.4	99.9
				76.8

## AIRPORT AND AIRWAY SYSTEM CAPACITY AND DELAY OVERVIEW

by  
Harvey B. Safeer  
Director of Aviation Policy and Plans

### I. CONCEPTS OF CAPACITY AND DELAY

Capacity and delay are illusive concepts, surrounded by confusion and misunderstanding. A substantial part of this problem is the result of multiple definitions being interchangeably used, and incomplete data being collected by multiple sources for varying purposes. The problem is further compounded by the difficulty in determining cause and effect relationships from the data which are available. The following discussion is intended to set the framework within which one can discuss the dual issues of capacity and delay.

#### A. CAPACITY

Two principle definitions of capacity have been advanced in discussions of terminal area capacity: (1) a so-called "practical" measure, and (2) a "throughput" measure (References 15, 20). The "practical" measure provides a measure of capacity which is defined with respect to a maximum acceptable average delay. (PANCAP is one well-known measure of this type.) The "throughput" measure is a measure of capacity independent of delay; it assumes that an aircraft will always be present waiting to use the terminal. A clear distinction between the two requires a brief description of the delay process.

If all users of a system consistently arrived at evenly spaced intervals, the system could provide service hourly to a number of users equal to the service time in minutes divided into 60. This is the maximum possible service rate and is the "throughput" measure of capacity. Unfortunately, system users do not arrive consistently at evenly spaced intervals. Sometimes several users arrive at one time and sometimes no one arrives. As a consequence, some of those who arrive at the same time as do others must be delayed. And at times no one is using the system. The "practical" capacity measure is the number of users that can be served hourly with the average user incurring delay of a certain level, after taking into account the unevenness of arrivals.

The two measures are illustrated by Figure 1 which indicates the theoretical relationship between capacity and delay. As can be seen, the "throughput" measure is the maximum capacity

attainable. It results in very high average delay levels--infinite at the limit--as a consequence of the unevenness of arrivals. The "practical" measure is less than the "throughput" measure. It is that level of capacity that corresponds to a given acceptable level of delay.

Although both measures have been used in studies of terminal delay, the "throughput" measure seems to have received more attention in later work (Reference 20). This is because it is relatively simple to calculate and independent of delay. In addition, being independent of delay, it is not affected by and will not vary with different delay calculation schemes. The "throughput" measure is thus comparable from situation to situation, regardless of the delay estimation techniques employed in each situation.

It should be pointed out that the relationship depicted in Figure 1 may not be directly observable in the real world. Figure 1 is drawn on the presumption of a single processing rate for all levels of operations. In reality, the processing rate often varies directly with the number of operations for a number of reasons. (See Section III for a more detailed discussion of the factors affecting the delivery rate.) Staffing levels are almost always positively correlated with expected traffic. Controller productivity may also increase as demand increases. And some systems (such as the en route airway system) may have more than one processing system (route between two terminals), each with a different processing time. As a waiting line develops behind the most efficient system, some of those waiting may turn to the second, third, and so on, most efficient system. Users served by these less efficient systems, while actually spending more time being served, will save enough time waiting for service to reduce overall time.

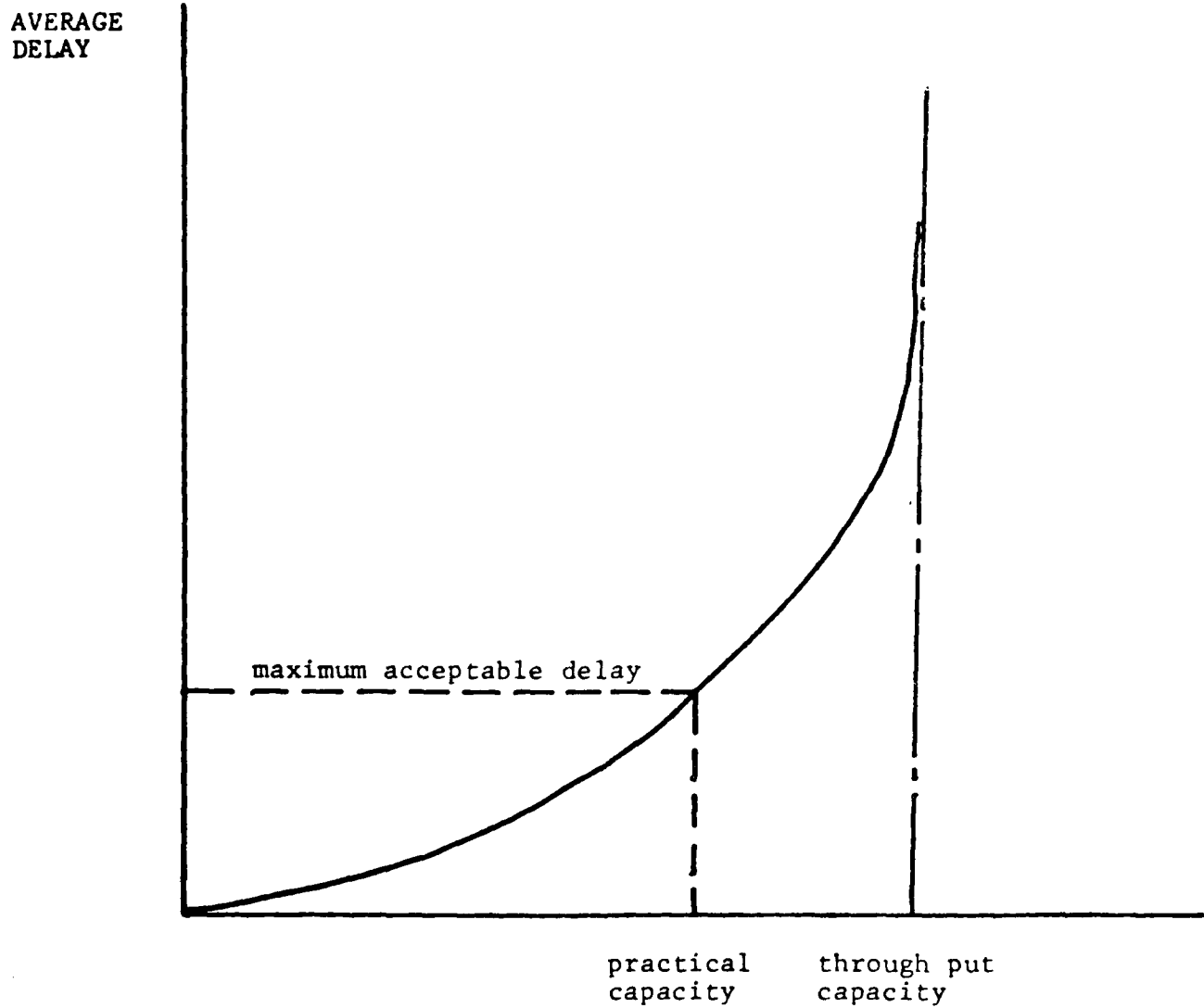
The impact of the processing rate increasing as the level of operation does will be to shift the delay-capacity relationships downward. The observed relationship will frequently be below the curve as drawn in Figure 1. And, if the processing rate should increase fast enough over a particular range of operations, the observed level of delay might actually decline over a particular range of operations.

## 8. DELAY

### 1. Acceptable Delay

Strictly speaking, delay will occur each time an aircraft is required to utilize other than the optimum route between two terminals. Whether or not this delay is significant, however, depends on that level of delay which is judged to

FIGURE 1  
RELATIONSHIP BETWEEN CAPACITY  
AND AVERAGE DELAY



NUMBER OF OPERATIONS

be "acceptable." "Acceptable" delay is, thus, a standard of the efficiency with which the en route system is expected to operate. Delays in excess of this level are an indication of substandard performance and are a signal that additional system expansion is required.

Adoption of "acceptable" delay standards is an exercise in public policy and is ultimately a political decision. Nonetheless, there are several criteria which the policymaker should consider in the establishment of these standards, including the following. First, part of all delay occurs because of conditions beyond anyone's control. Such conditions include variations in wind, weather, pilot proficiency and aircraft performance. Because there is little that can be done about such factors, there is little choice but to treat the delay they cause as "acceptable." Second, the economics of delay reduction investments should be considered. Under a strict economic criterion, investments in delay reduction should continue to be made until the benefits associated with such investments just equal the cost of undertaking them. The level of "acceptable" delay is that level which prevails when this economic condition obtains. "Acceptable" delay is, thus, that level of delay which it does not pay to eliminate. Third, the air traveler's ability to perceive small segments of time--say 30 seconds--might be considered. If it could be shown that air travelers are not aware of delays of 1/2, 1, 2, 3, or 4 minutes, it would be hard to justify investment expenditures to eliminate such delays to passengers. Fourth, it must be recognized that delay is a random phenomenon. Sometimes a flight between two terminals will experience small or no delays, while at other times delays will be large. This will generate problems in terms of scheduling, passenger connections, and maximum aircraft flying times. Accordingly, the policymaker must consider the maximum acceptable delay which, when encountered, would unduly disrupt the air transportation system.

## 2. Delay Classifications

Delay is commonly classified by the segment of airspace with which it is associated. This leads to confusion as to where aircraft actually experience delay and as to where the events that cause the delay occur. Information concerning the airspace segment where the factors which cause delay occur is important in that it focuses attention on segments of airspace with insufficient capacity. Knowledge of where the delays actually are experienced is important in that it identifies where the delayed aircraft

must actually be accommodated. Moreover, since some agency delay programs such as "flow control" seek to move delays from one air route segment to another, such information is essential if these programs are to be evaluated.

Figure 2 presents a matrix of delay classifications which indicates where delay originates and where it actually occurs. Airspace segments where delay originates are listed across the top. Airspace segments where delays actually occur are listed in the left margin. Each box is assigned a Roman Numeral-Letter designation and represents a different delay classification. The principal diagonal of the matrix--enclosed in the solid line--represents delays which occur in the same airspace segments as does its cause. Those boxes which are above the diagonal represent delays which take place in segments before the one in which the delay is caused. The shaded area which lies below the principal diagonal does not require classification.

FIGURE 2  
DELAY CLASSIFICATIONS

Location Delay Experienced	Departure-- Terminal (I)	Airspace Where Delay Caused		Arrival-- Terminal (IV)
		En Route (CONUS) (II)	En Route (Oceanic) (III)	
A. Departure Terminal	IA	IIA	IIIA	IVA
B. En Route		IIB	IIIB	IVB
C. Arrival Terminal				IVC

Delay caused in a particular airspace segment cannot actually take place in airspace segments which the aircraft encounters after the segment of delay origin. (As an

analogy, water backs up behind a dam, not in front of it.) An exception might be when departure delays cause arrival delays because there are too many aircraft on the airport surface to permit additional aircraft to be landed. Although these types of exception do occur, they are for the most part atypical. The following paragraphs describe each type of delay and where it occurs.

- a. Departure-Terminal: This delay (IA) is caused by events at the departure terminal and occurs exclusively at this terminal. The most frequent cause is weather. Because the situation is known to all potential departures, this type of delay is taken almost exclusively on the ground--where it is least costly.
- b. En Route (CONUS): En route delay occurs whenever an aircraft must take longer to complete a trip between two terminal areas than the minimum achievable time. Such delay occurs because the optimum route is not available for the aircraft for one of a number of reasons: (1) traffic volume between the two terminal areas may exceed that which may be accommodated by the optimum route, (2) severe weather may result in the optimum route being closed, (3) heavy traffic volume across the optimum route may require that an alternate route be flown.

Delays generated by en route events most likely will occur in the en route airspace (IIB). It is possible under extreme conditions that such delays may back up into the terminal area (IIA). If they do back up into the departure terminal, they will most likely be taken on the ground.

- c. En Route (Oceanic): En route oceanic delay, like en route CONUS delay, occurs when an aircraft takes longer to complete a trip than the minimum achievable. It is caused by the same factors as domestic delay. In the North Atlantic, limited optimum or near optimum air routes relative to demand for service are likely to be the primary cause. These delays may be experienced en route (IIIB) or be pushed back to the departure terminal area (IIIA) where they usually will be taken on the ground.
- d. Arrival Terminal: Delays generated in the arrival terminal airspace occur because the terminal cannot land aircraft at the rate they are arriving. This delay may actually occur in the terminal area (IVC)



but most often backs up into en route airspace (IVB) so as to avoid congestion in the terminal area and permit aircraft to hold at higher altitudes where they are more fuel efficient. (Note that most holding stacks are in en route airspace.) At times, these delays may back up all the way to the departure terminal where aircraft bound for congested terminals will be held on the ground (IVA).

## II. DELAY MEASUREMENT

There are four currently or potentially available sources of delay data.

### A. NATIONAL AIRSPACE COMMAND CENTER (NASCOM)

About sixty airports report on a daily basis their delays of 30 minutes or longer. These data are received at NASCOM and maintained by the Air Traffic Service. The data include a beginning and ending time for each series of delays, the number of delays during that period, and a primary and secondary cause of delays for that period. The determination of a NASCOM delay is, in practice, a subjective decision of the controller. The quality of reporting is subject to the variation in controller workload.

These data are readily available in a computer data base and provide a very broad view of serious delay problems. Their lack of precision limits their use in analyzing delay causes, but they may provide an immediate ability to monitor delay trends at a large number of airports.

### B. PERFORMANCE MEASUREMENT SYSTEM (PMS)

The Air Traffic Service also maintains, but not on computer, records of delays received through the PMS. These delays are officially described as being 15 minutes or longer but in practice shorter delays may be included. The definition and reporting of PMS delays are subject to the same constraints as NASCOM delays. The number of delays and airport conditions are reported by hour by about twenty airports.

### C. STANDARD AIR CARRIER DELAY REPORTING SYSTEM

Eastern Air Lines, American Airlines, and United Air Lines report delay data on about thirty airports to the Office of Aviation Policy. These are delays sorted by phase of flight and are in a computer data base. The causes of delays are not included, but the data provide a relatively detailed means of monitoring delay trends. The definition of a delay is based on a nominal standard for ground time and on computer-projected flight time.

#### D. OSEM SYSTEM

The Office of Systems Engineering Management developed a method of monitoring delay trends at airports, using CAB data on operational times actually experienced by air carrier flights. These data provide monthly estimates of the flight times between major airports. An arbitrary standard flight time must be subtracted to establish estimates of delays, but the results can be used to detect trends in delays.

Of the readily available sources of delay data, only the air carrier reporting system employs a standard of minimum flight time and systematically reports deviations from the standard.

### III. CAUSES OF AIRSPACE/AIRPORT SYSTEM DELAYS

FAA studies of delay at specific airports have identified six generic causes of airspace/airport system delay:

- o The proximity of other airports;
- o Air traffic control rules, regulations, and procedures;
- o Physical properties of the airspace/airfield;
- o Meteorology;
- o Operational procedures; and
- o Aircraft operating demand.

#### A. THE PROXIMITY OF OTHER AIRPORTS

The proximity of other airports to the specific airport being analyzed affects delays to the extent that their operations limit the paths over which aircraft may be vectored to or from the subject airport, or must be coordinated through approach control or the tower. Delays can be the result of a requirement to hold departures at one airport until arrivals have cleared at the other one, or a gap may be required in the arrival stream for one airport to accommodate arrivals to or departures from the other airport.

Delays may also be incurred when less than optimal routing is required in order to preclude incursion into the airspace of an adjacent airport. These routings can take the form of longer distances before turns are initiated in order to attain sufficient altitude to climb over conflicting approach paths or long approach legs at low altitudes to pass under conflicting flight tracks.

#### B. AIR TRAFFIC CONTROL (ATC) RULES, REGULATIONS, AND PROCEDURES

Although designed to ensure operational safety in the airport environment, certain ATC rules, regulations, and procedures limit, to some extent, total system capacities achievable and

affect delays. While ATC rules and regulations are absolutely necessary for safety of operation, their relationship to capacity and delay should be understood. The rules and regulations most affecting capacity and delay are those regarding separation requirements between arriving and departing aircraft. While it is not suggested that delay reduction be achieved through modifying the rules or procedures, one should understand why a certain level of delay is inherent any time you have a heterogeneous mix of aircraft operating at an airport.

1. Arrival Separations

At present, current ATC rules under IFR conditions stipulate that certain distances must be maintained between arriving aircraft of different weight classes. The current IFR separation standards are 3, 4, 5, 4, 6 nautical miles (LL, HH, HL, LS, HS)\*. In comparison, the separation under VFR is significantly less under saturated traffic conditions.

2. Runway Occupancy

The second basic ATC rule is that two aircraft may not both occupy the same runway. Once the first aircraft crosses the threshold, it has sole possession of the runway until it exits. The second aircraft must be spaced such that it does not cross the runway threshold until the first has cleared the runway.

3. Departure/Arrival Spacing

Current operating rules prohibit the initiation of a departure unless the following arrival is more than two miles out from the threshold.

4. Departure Separation

Current IFR operating rules define the minimum departing separation. Further, due to the wake vortex problem, VFR

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\*S, L, H refer to ATC weight classes:

Small (S): Less than 12,500#  
Large (L): Between 12,500# and 300,000#  
Heavy (H): Greater than 300,000#

Notation "HL" denotes heavy followed by a large aircraft. The notation "LL" includes all pairings not otherwise specified (i.e., SS, SL, SH, LL, LH).

standards for aircraft following a heavy are the same as IFR standards to ensure the safety of aircraft which takeoff after a heavy aircraft. The current IFR standards are HH: 90 seconds; HL, HS: 120 seconds; all others: 60 seconds.

C. PHYSICAL PROPERTIES OF THE AIRSPACE/AIRFIELD

The physical properties of an airport's airspace/airfield determine not only the ability of the entire system to accommodate various aircraft types, but also the operating efficiency, in terms of capacity and delay, of the configurations in which the airspace/airfield functions. The following are examples of physical properties which could influence delays:

- o Obstructions;
- o Displaced thresholds reducing usable runway length;
- o Shoulders on runways;
- o Intersection and exit locations and number;
- o Location of airline gates vis-a-vis runway exits; and
- o Weight limitations on runway segments.

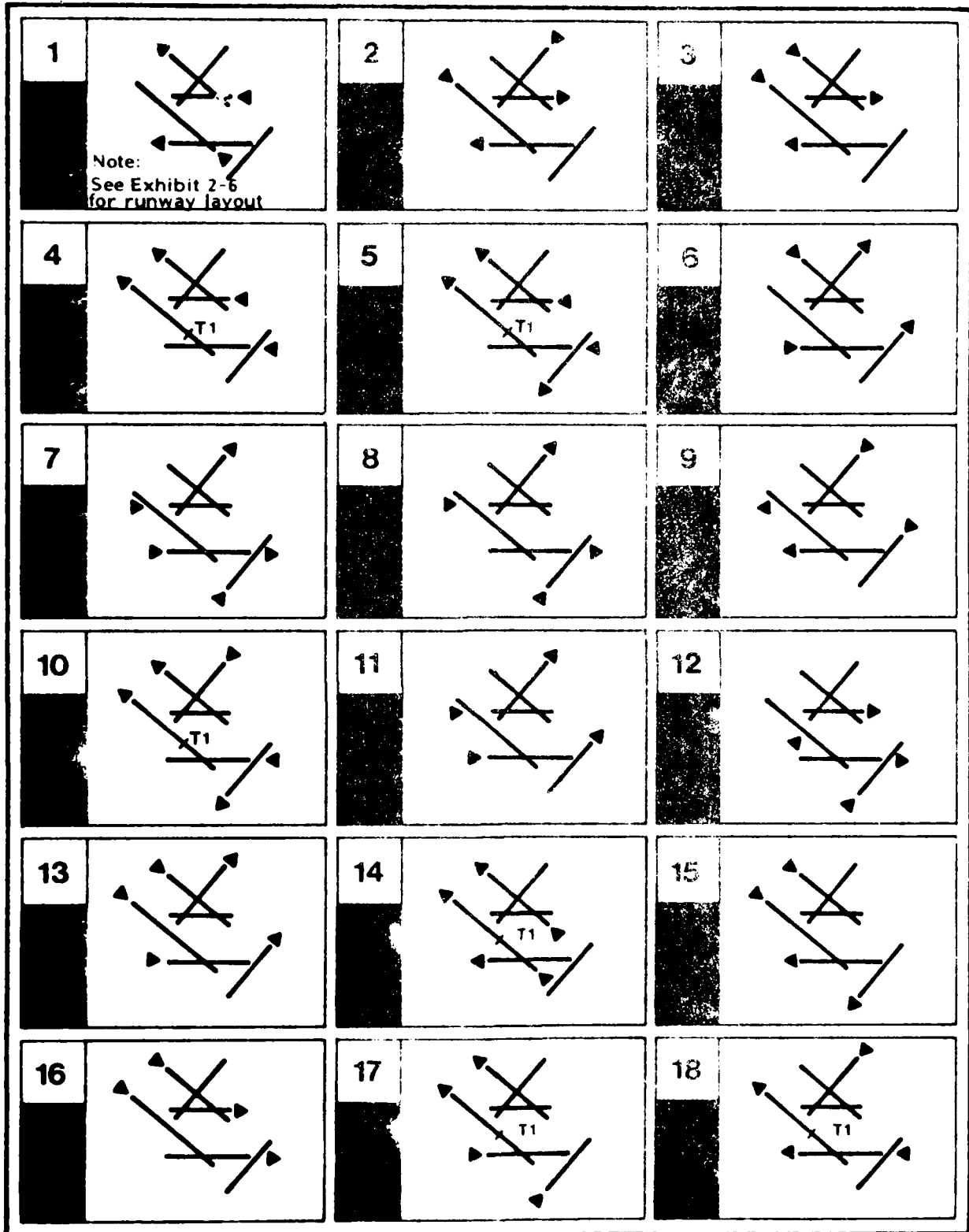
The significance of these physical limitations will vary from airport to airport.

D. METEOROLOGICAL CONDITIONS

The operational strategy of an airfield is governed to a large extent by considerations of ceiling, visibility, precipitation, and prevailing wind directions. These conditions determine not only what runway configuration will be in operation, but the control procedures to be used in processing aircraft to and from the field. Figure 3 shows 18 possible runway use combinations at O'Hare International Airport. An arrowhead pointing to a runway end indicates landing directions, an arrowhead emanating from the runway end indicates takeoff direction. Figure 4 shows the combined effects of weather (IFR versus VFR) and runway configuration specific capacity on average delay per operation. With a constant demand, average delay can range between 3 minutes per operation and 37 minutes per operation. Therefore, when the winds dictate the use of a high delay configuration, a premium in terms of increased delay, is paid for its use.

Ceiling and visibility also affect the selection of operating configurations. Depending upon instrumentation and conditions affecting their use, landing minimums can vary from runway to runway, necessitating adjusting the operating configuration to the prevailing ceiling and visibility conditions irrespective of

# RUNWAY CONFIGURATION - O'HARE INTERNATIONAL AIRPORT



O'Hare Delay Taskforce Study  
Chicago O'Hare International Airport

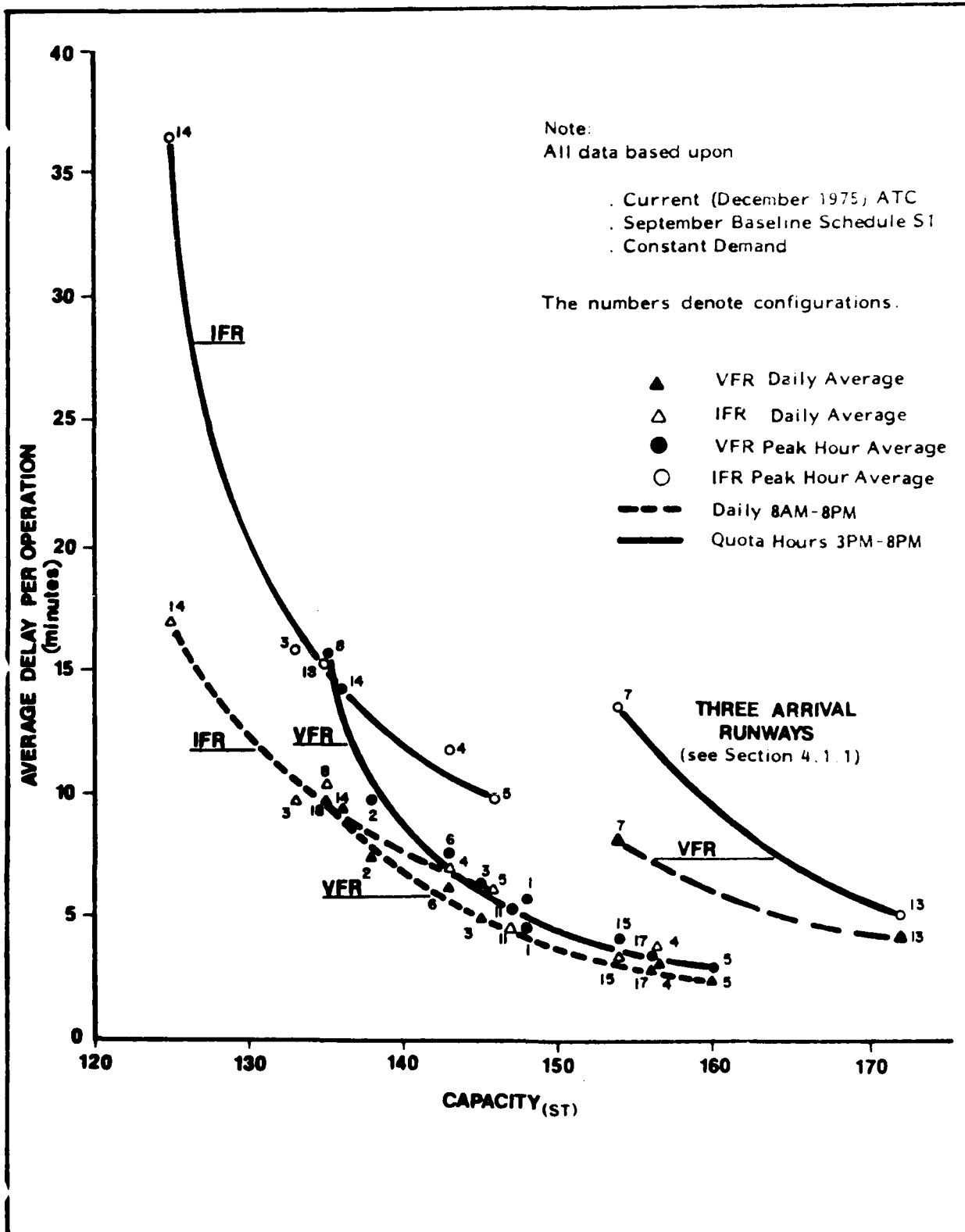
TITLE: **RUNWAY  
CONFIGURATIONS  
EXAMINED**



SOURCE:  
Landrum & Brown  
AIRPORT CONSULTANTS

EXHIBIT:  
**1-3**

**FIGURE 4**  
**DELAY VERSUS CAPACITY - O'HARE TASK FORCE STUDY**



O'Hare Delay Taskforce Study  
 Chicago O'Hare International Airport

TITLE: **DELAY VS CAPACITY (ST)**  
**DAILY AND PEAK HOUR**

SOURCE  
 Landrum & Brown  
 AIRPORT CONSULTANTS

EXHIBIT  
**3-8**

the capacity of the runway combination. As an example, meteorology can affect delays in even the most efficient configuration at O'Hare. Visual approaches (in which the pilot visually determines his own separation from the preceding aircraft) may not be conducted when the ceiling and visibility limits fall below 3,500 feet and 5 miles, respectively. This, in effect, causes an increased spacing between arrivals thereby decreasing capacity and increasing delay. As the ceiling and visibility approach IFR limits (1000/3), the spacing between arrivals again increases to allow a greater safety buffer between operations. In conditions of very low visibility, i.e., less than 500/1, visual observation of the runway system is not possible, requiring additional controller caution and increased dependence on pilot/controller communication, all of which further reduce the efficiency of the airfield system.

The condition of the runways themselves can increase spacing (therefore increase delays) by reducing aircraft braking performance thus increasing runway occupancy time. In addition, snow or ice on the runways will require periodic runway closures for maintenance to ensure safe operating conditions.

Short term phenomena such as ground fog or the passage of a frontal system accompanied by severe turbulence can result in the holding of departures on the ground and inbound aircraft in holding stacks. These conditions, although generally of short duration, often cause delays of major proportions due to the backlog of demand created.

#### E. OPERATIONAL PROCEDURES

The term "operational procedures" is meant to describe any procedural decision by airport management or FAA which influences:

- o The selection of operational configurations;
- o The changing of configurations throughout the operating day; or
- o The availability of runways for operational use.

Several considerations enter into the selection of operational configurations, most notably meteorology and, at some airports, noise abatement. While wind direction and velocity are key determinants in the selection and changing of runway configurations, selection decisions remain the responsibility of FAA air traffic control management (multiple configurations can be used for given wind conditions).

The changing of configurations throughout the operational day can contribute to delay. Some configuration changes are used to

adjust runway capacity to demand and create no delay problems. Other air traffic control towers operate under a policy which requires periodic runway rotation for noise abatement purposes when wind and weather permits. Additional configuration shifts are required when wind velocity and ceiling and visibility necessitate a change in arrival and/or departure runway orientation.

The unavailability of runways for use due to scheduled maintenance, construction, and weather related problems, such as snow removal, also contributes to delay. To a large extent, unavoidable weather related problems are the primary reason for unscheduled "down" runways. However, scheduled maintenance and construction are a necessary and on-going function of any airport operation which can contribute to delays. Airport management procedures have not always provided for detailed operational analyses prior to maintenance and construction scheduling, and coordination among aircraft and airport operators and the air traffic control management has not always occurred to the extent that the delay consequences of construction activities have been minimized.

#### F. AIRCRAFT OPERATING DEMAND

Simplistically, all airports can be divided into two broad generic classifications:

- o Origin/Destination; and
- o Connecting

Origin/destination airports are characterized by large percentages of passenger traffic either starting or ending their trip at the city served by the airport. Some of the passengers may be making connections and there may be connecting traffic between commuter airlines and larger air carriers, but this represents a relatively small proportion of the total traffic.

Connecting airports, on the other hand, are typified by a relatively large percentage of passengers transferring between aircraft. This connecting complex role manifests itself in a demand pattern which tends to bunch arrivals and departures in blocks providing the capability to interchange connecting passengers in a high level of activity during the hours of the day which provide access to the various markets served with reasonable arrival and departure times. The existence of a connecting complex, with its attendant delay problems, provides benefits to the extent that:

- o An otherwise uneconomical level of service to many communities, large and small, is provided by means of through planes and connecting schedules.



- o The total level of operations is less than would otherwise be required to carry passengers and cargo between many city pair markets.

An extreme example of a connection operation is Atlanta's Hartsfield International Airport, as shown in Figure 5. On an hourly basis, operations alternate between predominantly arrivals or departures. For a given level of demand, and a given runway configuration, the relative mix of arrivals and departures will have an effect on the level of delay encountered.

#### IV. ESTIMATES OF AIR CARRIER DELAYS

There is no reporting system or combination of reporting systems which provide information about the total delays in the system and the possible causes of delay. Data from two of the systems are discussed, along with some of the implications of the data provided.

##### A. NASCOM DELAYS

As discussed previously, there are a number of different systems for reporting air carrier delays. The most commonly used system within the FAA is the NASCOM system of reporting air traffic delays of 30 minutes or more. This system does not provide a measure of the amount of delay, e.g., total minutes, but rather is a measure of the number of operations experiencing delays of 30 minutes or more. To the extent that it does provide information, that information is limited to the most severe types of delays. Total NASCOM delays have been increasing. Between 1976 and 1979, total operations delayed 30 minutes or more increased from 36,000 to about 62,000. Delays also increased relative to the number of operations, from 3.4 to 5.2 delays per 1,000 operations.

While total NASCOM reported delays have been increasing, there have been no dramatic changes in the causes of NASCOM delays. Data for the four years are summarized in Table 1. The predominant cause is adverse weather, accounting for three-fourths or more of the delays each year.

FIGURE 5

ATLANTA, GA.  
ATL  
SCHEDULED OPERATIONS  
FRIDAY - AUGUST 4, 1978

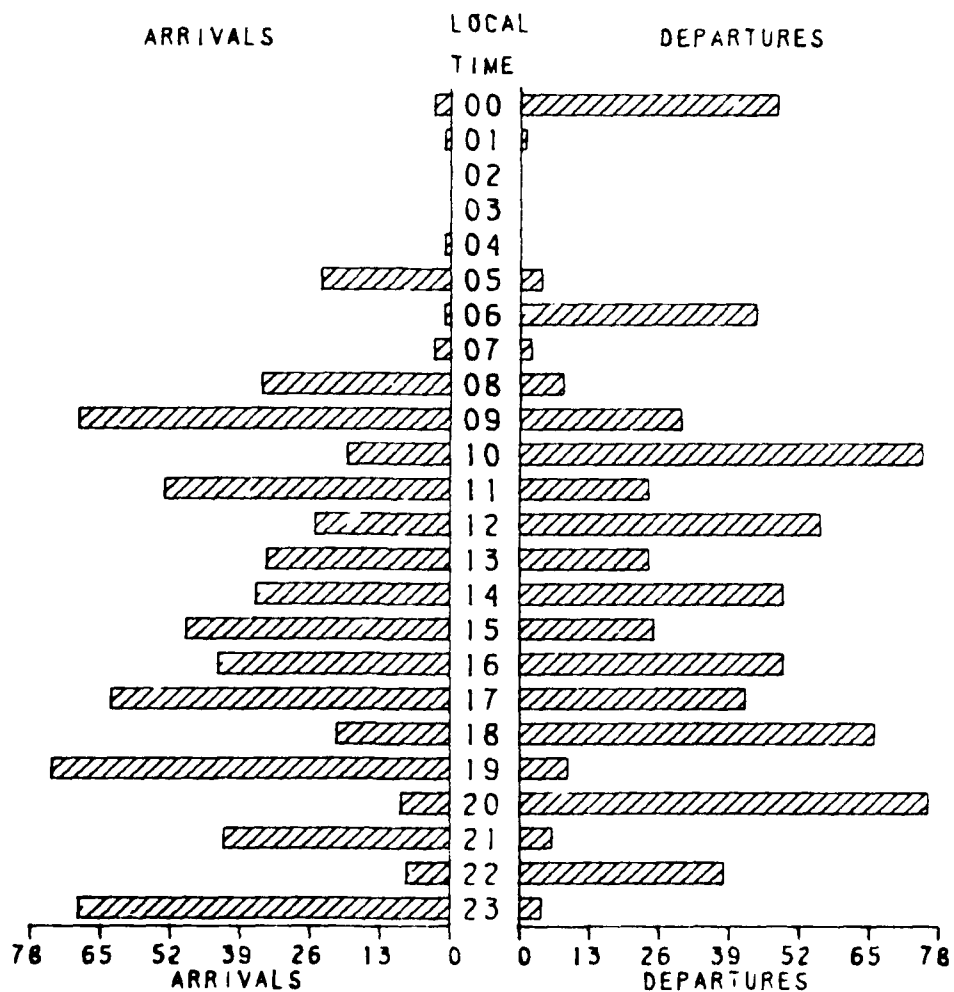


TABLE 1  
NASCOM DELAYS

	1976	1977	1978	1979
Total Delays	36,196	39,063	52,239	61,598
Weather	76%	83%	79%	84%
Equipment Failures	4%	2%	7%	3%
Weather & Equipment Failures	11%	5%	3%	4%
Other Causes	9%	10%	11%	9%
Total Delays Per 1,000 Operations	3.4	3.5	4.6	5.2

While weather may be the primary cause, it cannot be completely separated from the other factors discussed in Section III.

B. STANDARD AIR CARRIER DELAY REPORTING SYSTEM

The Standard Air Carrier Delay Reporting System provides detailed information about delays classified by type of delay, but not by cause. The types of delay measured, and their definitions, are:

- o Taxi Out Delays--Determined by measuring the difference between actual taxi out time for an aircraft and a preselected standard for each aircraft type and airport operated out of. The standards developed were based on the first ten percentile time of taxi out distributions considering one complete year's worth of operations for each aircraft type at each airport operated. Where experience for particular aircraft types at airports did not exist, a time relationship was developed and extrapolated from those airports where multiple equipment types were operated. In no case was a standard (as a minimum) to be less than three minutes.
- o Taxi in Delays--Determined the same way as taxi out delays, except that the minimum standard for any equipment type at any airport would not be less than two minutes.
- o Airborne Delays--Computed as the difference between actual airborne time (off-to-on time) and each respective air carrier's computer flight plan airborne time - when it exists. The computer flight plan time considers winds and temperatures aloft (thus nullifying their variability), has an allowance for vectoring in the terminal areas, and is, by policy of each air line, the route/altitude to be flown.  
  
Some routes of low stage length do not have a computer flight plan. In these cases, a standard airborne time was developed based on a linear regression relationship of airborne time dependent upon route miles as determined from actual, uncongested airborne experience by equipment type.
- o Gate Delay Measurements--Are derived from each carrier's delay code reporting system, wherein delay times at the gate and delay codes (signifying the reason) are input by airport personnel. In the Standard Air Carrier Delay Reporting System gate delays are reported for (1) ATC clearance, (2) weather, (3) ramp congestion, and (4) flow control.

The air carrier data indicate that the average delay per flight increased from 11.13 minutes to 12.46 minutes from 1977 to 1979. Data for each of the four flight phases are summarized in Table 2 for 1977 through 1979.

TABLE 2  
DELAY BY PHASE OF OPERATION

Phase of Operation	Average Delay per Flight, Minutes		
	1977	1978	1979
Gate Hold	.12	.12	.13
Taxi Out	4.51	4.78	5.07
Airborne	4.27	4.36	4.75
Taxi In	<u>2.23</u>	<u>2.41</u>	<u>2.51</u>
Total	11.13	11.67	12.46

Since the average delay per flight is calculated by considering all flights, including those which experience no delay, it is worthwhile to investigate the distribution of delays among all flights. Such a distribution is available for each phase of a flight from the Air Carrier data, but not for entire flights. The distribution of delays for each of the four flight phases is summarized in Table 3.

TABLE 3

FREQUENCY DISTRIBUTION OF GATE HOLD DELAYS,  
TAXI OUT DELAYS, AIRBORNE DELAYS, AND TAXI IN DELAYS  
EXPERIENCED BY AIR CARRIER FLIGHTS

Minutes of Delay	Percent of Flights			
	Gate Hold	Taxi Out	Airborne	Taxi In
0	98.9%	12.2%	39.5%	17.2%
1	0.1	11.9	7.3	26.6
2	0.1	14.3	7.6	22.1
3- 4	0.1	25.6	14.2	21.9
5- 9	0.2	24.7	18.9	9.4
10-14	0.1	7.0	6.8	1.7
15-19	0.1	2.5	2.4	0.6
20-24	0.1	1.0	1.0	0.3
25-29	0.0	0.4	0.5	0.1
30-44	0.1	0.4	0.7	0.1
45-59	0.0	0.1	0.4	0.0
60+	<u>0.0</u>	<u>0.1</u>	<u>0.4</u>	<u>0.0</u>
	100.0	100.0	100.0	100.0

Note: Percentages may not sum to 100.0 due to rounding.

The tables above indicate that we may assume that a clear majority of flights encounter a total delay below the

average. Combining the results presented in these tables, we note that:

- (1) About 99 percent of flights encounter no gate hold delays;
- (2) About 64 percent of flights encounter a taxi out delay of four minutes or less below the average;
- (3) About 69 percent of flights encounter an airborne delay of four minutes or less below the average; and
- (4) About 66 percent of flights encounter a taxi in delay of two minutes or less below the average.

The Air Carrier data also enable us to compare the average delays at individual airports. The average delays for 1977 through 1979 at thirty airports are summarized in Table 4. The 1979 average delay is lower than the 1977 average delay at only three of these airports. The upward trend in delays cannot simply be attributed to higher levels of operations, as evidenced by the diversity of changes in delay levels and operations levels summarized in Table 5.

TABLE 4  
AVERAGE DELAY PER OPERATION AT  
SELECTED AIRPORTS, 1977-1979, IN MINUTES

Airport	1977	1978	1979
ATL	10.39	9.93	10.54
JFK	9.58	10.75	9.85
ORD	9.05	9.33	10.12
LGA	8.06	9.17	10.56
EWR	7.23	7.70	8.08
BOS	7.16	6.72	8.61
DEN	6.98	9.23	8.70
DCA	6.72	6.50	6.91
PHL	6.45	8.27	6.77
STL	5.79	5.98	6.85
PIT	5.67	5.73	5.84
HNL	5.44	5.54	5.75
MIA	4.95	5.38	5.35
LAX	4.87	5.19	6.45
IAD	4.78	4.74	5.54
SFO	4.78	4.50	5.09
CLE	4.68	4.48	4.59
DTW	4.36	4.59	4.77
DFW	4.32	4.61	4.79
IAH	4.08	4.83	5.98
MSY	3.86	4.39	5.03
CHS	3.80	3.67	3.46
RAL	3.76	3.98	4.24
IND	3.73	3.94	3.83
JAX	3.66	3.62	3.61
TPA	3.61	4.17	4.32
SEA	3.48	3.37	4.09
RDU	3.47	3.78	3.85
MEM	3.20	3.48	4.24
MSP	3.14	3.08	3.51



TABLE 5  
AVERAGE DELAY PER OPERATION AND TOTAL NUMBER OF  
OPERATIONS AT SELECTED AIRPORTS, 1977 AND 1979  
(Delays in Minutes)

Airport	1977		1979	
	Delay	Operations	Delay	Operations
ATL	10.39	508,163	10.54	594,410
JFK	9.58	335,473	9.85	325,748
ORD	9.05	735,272	10.12	735,524
LGA	8.06	351,642	10.56	353,968
EWR	7.23	197,404	8.08	211,179
BOS	7.16	332,191	8.61	355,959
DEN	6.98	452,549	8.70	482,389
DCA	6.72	342,001	6.91	351,485
PHL	6.45	328,746	6.77	344,630
STL	5.79	332,289	6.85	341,854
PIT	5.67	317,779	5.84	346,838
HNL	5.44	330,573	5.75	411,376
MIA	4.95	313,447	5.35	378,939
LAX	4.87	495,312	6.45	547,960
IAD	4.78	189,749	5.54	176,196
SFO	4.78	342,578	5.09	363,791
CLE	4.68	243,028	4.59	265,397
DTW	4.36	255,363	4.77	285,445
DFW	4.32	379,903	4.79	436,362
IAH	4.08	229,408	5.98	295,523
MSY	3.86	165,052	5.03	198,623
CHS	3.80	142,768	3.46	156,427
BAL	3.76	242,960	4.24	218,662
IND	3.73	214,350	3.83	212,619
JAX	3.66	121,912	3.61	132,892
TPA	3.61	195,600	4.32	241,795
SEA	3.48	185,836	4.09	208,721
RDU	3.47	104,793	3.85	206,997
MEM	3.20	326,547	4.24	369,069
MSP	3.14	264,248	3.51	282,750

Finally, the Air Carrier data help present a picture of the trends in systemwide delays. Various measures of delay are summarized in Table 6, the main conclusion being that delays are generally increasing in number and cost.

TABLE 6  
VARIOUS MEASURES OF DELAY AS REPORTED BY  
SELECTED AIRLINES, 1976-1979

	1976	1977	1978	1979
<u>Total Hours of Delay (000's):</u>				
Eastern	103	112	119	125
Eastern, United, and American	256	270	296	N/A
<u>Average Minutes of Delay Per Operation:</u>				
Eastern	5.9	6.3	6.5	6.7
Eastern, United, and American	5.5	5.6	5.8	N/A
<u>Total Delay Cost (000,000's):</u>				
Eastern	\$ 97	\$108	\$121	\$135
Eastern, United, and American	\$221	\$258	\$225	N/A
<u>Average Delay Cost per Operation:</u>				
Eastern	\$ 93	\$102	\$111	\$121
Eastern, United, and American	\$ 78	\$ 89	\$ 74	N/A
<u>Gallons of Fuel Consumed in Delay (000,000's):</u>				
Eastern	87	92	99	106
Eastern, United, and American	228	235	255	N/A

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## TODAY'S ATC SYSTEM - PROBLEMS AND NEED FOR CHANGE

by  
Raymond Van Vuren  
Director, Air Traffic Service

I have been asked to talk to you today about our contemporary Air Traffic Control System, or ATC System as we call it.

In doing so, I will first trace its historical evolution before describing what it is today. Later, I'll conclude my talk with a frank discussion about some of our concerns about the system.

The evolution of our ATC System began in 1920 when the Post Office Department established four Aeronautical Stations to support its trancontinental airmail route. These stations maintained, what can now be described, an archaic system of navigational aids, or more accurately, beacon lights along the route.

During the late 1920's, some municipal governments began to provide some limited air traffic control at airports by using light signals, or light guns as they are called today.

By the end of this decade, the city of Cleveland had established the use of radio communications to control airport traffic. Twenty other cities quickly followed Cleveland's example.

Earlier, on May 26, 1926, an Air Commerce Act was enacted. This Act, among other things, directed a civilian agency, the Department of Commerce, to establish and operate an airway system and maintain aids to air navigation. By the end of the year, the first Federal Air Regulations, or FARs as they are called today, were promulgated.

In 1935, methods for controlling airport and airway traffic were drafted at a conference of government and airway user groups.

A year later, the government assumed operation of the three existing airway traffic control centers which had been operated by the airline companies.

In 1938, the Civil Aeronautics Act added to the responsibilities mandated under the Air Commerce Act by establishing the Civil Aeronautics Authority, or CAA, which was the predecessor of the Federal Aviation Agency.

The next significant milestone occurred in 1941 when the CAA, for the first time, began to operate the airport traffic control towers. Then came World War II with its tremendous growth in aviation and U.S. air power. This dictated the need for the common system we have today for the control of both civilian and military air traffic.

Other milestones were the creation of the Federal Aviation Agency in 1958 and its later consolidation as the Federal Aviation Administration under the Department of Transportation in 1966.

The system of the 30's and 40's, which we term the "First Generation System," relied solely on air/ground radio communications. It consisted of an air navigation network and a manual control system based exclusively on time interval separation between flights.

After World War II, radar was introduced. The addition of this revolutionary ATC tool formed the basis for the "Second Generation System"; the system of the 50's and 60's.

During the 1950's, radar was systematically deployed throughout the system along with other new and improved equipment. Its use provided the air traffic controller a real-time electronic depiction of the position of all aircraft under his control.

In general, the more extensive use of radar greatly decreased the amount of airspace assigned to each aircraft, thereby greatly increasing the efficiency of the system.

In the early 1960's, the Air Traffic Control Radar Beacon System (ATCRBS) was introduced. This system, which consists of airborne radar beacon transponders and ground-based radar beacon interrogators and receivers, formed the basis for today's system, the "Third Generation System."

In retrospect, you can now see that our ATC system evolved from, and is based on, three unique type facilities, plus a fourth which I will shortly identify.

First, there is the Air Route Traffic Control Center (ARTCC) which evolved from the Airway Traffic Control Center operated by the airlines.

Second, there is the Airport Traffic Control Tower (ATCT) which evolved from the early control towers which were operated independently by local government.

Third, there is the Flight Service Station (FSS) which evolved from the aeronautical stations operated by the Post Office Department.

Lastly, there is a fourth unique type facility, the Air Traffic Control System Command Center, which was established in 1970. This was in response to isolated clusters of congestion which occasionally disrupted the system.

I will now, in the brief time that we have, attempt to describe today's system-a system of facilities.

Today's system, the "Third Generation System," the system of the 70's and early 80's, is generally organized around the ARTCC, or Center, as we call it. These facilities provide separation service for all aircraft operating under Instrument Flight Rules (IFR) in airspace governed by the U.S.

The airspace has been divided into 25 geographical areas. Each of these areas is under the jurisdiction of a center. Twenty reside within the conterminous U.S. (CONUS); the remaining five in Alaska, Hawaii, Puerto Rico, Guam, and Panama.

The original center boundaries were generally drawn to conform with the geographical boundaries of the states within a particular FAA Regional Office's jurisdiction. This was intended to facilitate determining regional airspace configuration, along with other factors, makes needed changes in national airspace difficult to implement.

To provide a manageable system within the Center, the airspace is further divided both horizontally and vertically into blocks of airspace called sectors. The sectors are classified by altitude: ultra high altitude at and above flight level 370; high altitude at and above flight level 180; low altitude below flight level 180. Other airspace, usually below 7,000 feet AGL and within 35 miles of a terminal radar facility, is released to terminal approach control facilities.

It will be helpful to you at this time to note that altitude at and above 18,000 feet MSL are called Flight Levels. They are based on aircraft altimeter readings set to correct for a constant mean sea level barometric pressure of 29.92 inches of mercury.

The vertical aircraft separation minima applied by the center is based on altitude level: A 1,000 feet minima up to and including flight level 290; a 2,000 feet minima above flight level 290.

When not applying vertical separation, the following horizontal radar separation may be applied:

Below flight level 600 - 5 miles

At or above flight level 600 - 10 miles

You should also note at this time that aircraft operating above 12,500 feet MSL are, by regulation, required to have an operating Mode C altitude reporting transponder.

Additionally, a Positive Control Airspace (PCA) has been established for approximately all airspace at and above flight level 180 in the CONUS. In addition to the Mode C transponder, the aircraft must operate under an IFR flight plan.



The air traffic control positions of operation within the Center are, quite naturally, also called Sectors. They are usually situated such that adjacent sectors control adjacent airspace.

The controller positions of operation at each sector are typically the "Radar Controller," "Data Controller," "Assistant Controller," and "Coordinator."

Through the use of full digital radar displays called plan view displays, or PVDs, computer input devices, air/ground radio communications, landline communications between other sectors, adjacent centers and terminal approach control facilities, and paper strips called flight progress strips, the radar controllers separate and provide services sector-by-sector as the aircraft traverse the Center's airspace.

The PVD is driven by an ATC automated system called NAS En Route Stage A. This system, which is an IBM 9020 computer, is in operation at all 20 Centers within the CONUS. It is a large and complex system which accomplishes many functions simultaneously. These functions consist primarily of Radar Data Processing (RDP), Flight Data Processing (FDP), Radar Simulation (DYSIM), and Data Recording.

The FDP function performs flight plan composition and storage, route processing, updating, and automatic transfer of flight data within the Center, between the Center and the adjacent Center, and the Center and its associated terminal facilities.

The RDP function performs primary radar and beacon target processing of target reports received from our Radar Digitizers (CDS) at the Long-Range (ARSR) sites, precise tracking of aircraft, automatic handoffs of aircraft between the sectors, adjacent centers and associated automated terminal facilities. It displays these data as target symbols, history trails, and data blocks. The data block is automatically associated with the aircraft target and contains essential information, such as aircraft ID, assigned altitude, reported altitude, and ground speed.

To assist the controller in maintaining an equitable distribution of delays and an optimum arrival interval between landing aircraft at our major airports, en route metering is employed. This function, which is now accomplished manually through controller judgements, will soon be automated. Precise calculations of the time and speed at which an aircraft should depart an outer metering fix will be made based on real-time flight data. Arrival sector controllers will receive this information in the form of sequenced aircraft arrival lists and metering fix crossing times displayed on their PVDs.

The controller will, in turn, adjust airspeed or radar vector to ensure that the aircraft crosses the metering fix at the optimum time. The

computer program will be delivered to the field in December. After a 90 day test, evaluation and controller training period, we expect the first center to be operational in March, the last in July.

There are a multitude of other en route functions such as flow control, en route metering, search and rescue coordination, military mission coordination, training, and the like that would require a much lengthier discussion.

Also, Military Training Routes (MTRS), Military Operating Areas (MOAS), Preferential Routes (PDARS, STARS), and profile descent about which time does not permit me to discuss.

As you recall, I mentioned that there were also five Centers outside the CONUS. Three of these low-activity, offshore Centers have recently received the EARTS system.

This system is essentially an ARTS-III, which I will shortly describe, but has been modified to accept digitized radar data from any combination of up to five long-range (ARSR) or short-range (ASR) radars. Another notable exception is that it employs full digital radar displays, or PVDS, in common with the other larger centers.

The next facility in our system of facilities is the Airport Traffic Control Tower, or tower, as we call it.

The tower provides ATC service in the vicinity of airport. Where traffic volume is moderate to heavy, the facility consists of both the tower and a Terminal Radar Approach Control called a TRACON.

Today, there are approximately 500 towers of which about 50 percent are associated with either an integral or separate TRACON. Others are provided radar approach service by the center sectors where radar coverage permits.

Today's towers fall into three categories: the VFR Tower, the Nonradar Approach Control Tower, and the Radar Approach Control Tower.

The VFR Tower essentially consists of three positions of operation, or control positions, as they are called at terminals, they are "Flight Data", "Ground Control," and "Local Control." The latter position provides visual control of aircraft while they are departing, arriving or flying in the local traffic pattern; the former are self-explanatory.

The functions of the VFR tower are sequencing arrival and departure traffic and the separation of aircraft on the ground.

The nonradar approach control tower differs from the VFR tower in that it provides separation services to aircraft operating IFR through

precise ATC procedures. It accomplishes this through the addition of an approach control position. The approach controller separates aircraft by assigning various nonconflicting routes, altitudes, and time restrictions to aircraft under his or her control.

Lastly, there is the radar approach control tower. These facilities are established in terminal areas that have moderate to high traffic densities where radar can expedite the flow of traffic.

This facility consists of a tower cab, which is essentially the same as the VFR tower, with the addition of a Brite radar display, and, most importantly, a TRACON.

The TRACON consists of a large room within which the radar operation is housed and conducted. A number of radar approach control towers are what we term TRACABS. In the TRACAB, the approach control function is performed using a Brite radar display in the tower rather than in a separate room.

The TRACON is, in essence, a small center which provides ATC and other radar services in the terminal airspace delegated to it by the Center. This airspace is usually that airspace within 35 miles of the primary airport and below 7,000 feet AGL. The exceptions to this rule are the larger TRACONS such as the New York and O'Hare TRACONS. Each of these larger TRACONS control traffic into and out of a number of primary and satellite airports.

Its typical positions of operation are "Approach Control," "Departure Control," "Flight Data," and "Coordinator." The busier may include, in addition to multiple positions, "Parallel Approach Monitors." These latter positions monitor aircraft conducting simultaneous instrument approaches to parallel runways.

The TRACON controllers provide essentially the same type of service as their counterparts at the Center. The significant difference being that the service is provided within smaller divisions of airspace using reduced aircraft separation minima and a high degree of vectoring.

The following separation minima is applied in the terminal environment:

#### Horizontal Radar Separation

5 miles if aircraft 40 miles or more from the antenna

3 miles if less than 40 miles from the antenna

1 1/2 miles for participating VFR aircraft when within 15 miles of the antenna

## Vertical Separation

IFR Aircraft - 1,000 feet

Participating VFR Aircraft - 500 feet

A participating VFR aircraft is one that is voluntarily receiving radar separation services within a Terminal Radar Service Area, or TRSA, as we call it.

If the VFR aircraft is operating in a Terminal Control Area (TCA) the service is mandatory. The TCA is, in effect, an area of positive control airspace surrounding a major airport.

We have, to date, established 22 TCAs and 135 TRSAs.

All of our terminal radar facilities include some degree of automation dependent on traffic loads; ARTS-III and ARTS-IIIA at our high traffic density facilities, ARTS-II at our moderate traffic density facilities, and TPX-42 at our light traffic density facilities.

It may be helpful to point out at this time that air carrier passenger loads are appropriately factored in when determining which facilities get which equipment.

ARTS III, which provides a fairly high degree of automation, is in operation at 64 of our major terminal facilities. It consists of a Data Acquisition Subsystem (DAS), Data Processing Subsystem (DPS), and a Data Entry and Display Subsystem (DEDS).

Simply put, this system provides the terminal controllers the same kinds of information that NAS en route Stage A system provides their en route counterparts. However, there are some notable exceptions.

The information, that is, the target symbols and data blocks, are presented to the controller on time-shared radar displays, or, Plan Position Indicators (PPIS), along with broadband primary radar and beacon targets. Consequently, two systems, the old system and the new system, are concurrently in operation. This provides an immediate backup in the event of an ARTS System failure.

Another exception is that the basic ARTS III System does not receive primary radar information from nontransponder equipped aircraft. Consequently, these aircraft are handled in the "Second Generation" manner using the concurrent broadband display feature.

ARTS IIIA is an enhancement of the basic ARTS III System. It includes primary radar target tracking, autorecovery after a computer failure, and Continuous Data Recording (CDR).

This enhancement will be installed at 26 of our major terminal facilities. It is now in operation at the Tampa TRACON and will soon be commissioned at the second planned site, the New York TRACON.

ARTS II, which provides a somewhat lesser level of automation, is in operation at approximately 70 of our facilities with more on the way.

Again, it can best be described by comparing it with a previously described system, the basic ARTS III. It is essentially the same except that it performs no tracking. Target symbols and accompanying data blocks are associated with the Beacon targets at the reported position (Radar X-Y) on a scan-by-scan basis. If the target report is missing; e.g., a garbled Beacon reply, the alphanumeric data is frozen at the last reported position rather than displayed at the predicted position as in ARTS III.

Lastly, there is the TPX-42 System. This system is in operation at 35 of our lower activity terminal facilities and also a large number of military ATC facilities.

The TPX-42, in essence, a smart beacon decoder system which includes a very low level of automation. It receives and decodes beacon replies and displays the resulting data as target symbols and limited data blocks. The data block consists of the numeric octal beacon code and reported altitude if a Mode C reply was received.

These systems will be eventually replaced by ARTS II.

In addition to the features that I have very generally described, most of our automation systems include some recent safety enhancements:

Conflict alert in NAS en route Stage A and ART III, Minimum Safe Altitude Warning (MSAW) in ARTS III, and Low-Altitude Alert System (LAAS) in TPX-42.

These safety enhancements are also planned for our ARTS II System in future budgets.

Unfortunately, time does not permit discussing further functions and aspects of our terminal ATC System.

The next of our unique type facilities is the Flight Service Station, or FSS. These vital facilities have the prime responsibility for conducting preflight briefings, en route communications with VFR flights, assisting lost VFR aircraft, originating Notices To Airmen (NOTAMS), disseminating aviation weather information, accepting and closing flight plans, monitoring radio navigational aids (NAVAIDS), participating with search and rescue units, and last, but not least, operating the national weather teletype systems.

In disseminating en route weather information, the FSS employs an Enroute Flight Advisory Service, or EFAS, as we term it. This service was first implemented on the West Coast in 1972 to provide real time weather reports directly to pilots inflight on dedicated frequencies. This service, which has reduced weather related accidents, is now provided at 44 locations.

EFAS facilities will be equipped with digitized weather radar displays in the very near future.

We are now embarked upon a major FSS automation modernization program to improve service to the users.

As an essential element of this program, we have reviewed the number and location of existing FSSS with a focus towards consolidation. Upon completing our review, we have tentatively selected 61 FSSS to receive automation. Factors such as general aviation activity, airport operations, and based aircraft were considered in our decision. These locations are centers of general aviation activity and not necessarily the same location as the existing FSSS.

The automated FSS, which will be housed in newly constructed buildings, will be phased in over the next 5 to 7 years. It will introduce a number of new capabilities which will ultimately provide specialists with rapid access to weather information and the ability to provide instant processing of flight plans. Additionally, telephone "bottlenecks" will be eliminated by enabling the user to access the system directly to obtain briefings and file flight plans without the assistance of a specialist.

There are currently 319 FSSS in operation. They range from very small "One-Man" facilities to large facilities employing more than 100 people.

Many positions of operation are involved in the operation of the FSS system which would require a separate briefing.

Lastly, there is the Air Traffic Control System Command Center (ATCSCC). This single facility is located in our Washington Headquarters building.

It consists of five distinct operational components: Central Flow Control, Airport Reservations Office, Central Altitude Reservation Office, Contingency Command Post, and a National Weather Dissemination Service.

Central Flow Control is accomplished by a Central Flow Control Facility, or CF2, as we call it. This facility is intended to, in effect, manage the flow of air traffic throughout the nation to ensure optimum efficiency, safety, and economy.

To enable its operation, it employs an array of equipment and communications outlets, including a remote computer complex at Jacksonville, Florida. Unfortunately, this equipment has yet to be developed to the extent necessary for the Central Flow Function to be performed as intended.

The Airport Reservation Office (ARO) was established to relieve congestion at four of our busiest airports: O'Hare, Kennedy, La Guardia, and Washington National. It accomplishes this task by requiring reservations during high traffic activity hours to reduce the activity to a more efficient level.

The Central Altitude Reservation Office (CARF) exists primarily to support the military and assist Local Flow Control specialists at the Centers. It accomplishes this by providing detailed, easily interpreted assessments of pending military exercises, including air refueling operations, missile launchings, and the like which require special airspace protection.

Additionally, CARF serves as our coordinating agency for processing airspace reservation requests which will traverse foreign airspace.

The Contingency Command Post (CCP) becomes activated when a major calamity occurs somewhere within the ATC system.

Examples of a major calamity would be a catastrophic failure at one of our Centers or a widespread, and I might add, illegal controllers' strike.

The last of the functions of the Command Center is its weather service. Specifically, its assembly, analysis, and dissemination of existing nationwide weather reports. This includes upper air situation, orientation of the jet stream, areas of clear air turbulence, and forecasts of terminal weather conditions.

In concluding this part of my talk, I would like to throw some numbers at you that should assist you in appreciating the size of our Air Traffic Control System and the extent of its services.

Air Traffic Control Specialists	21,000
Flight Service Specialists	5,000
Expert Technicians	10,000
ARTCCs	25
ATCTs	431 (FAA)
FSSs	319
Air Route Surveillance Radars	124
Airport Surveillance Radars	195
Radio Communications Air/Ground	562
VOR/TACAN/DME	1,000
Instrument Landing Systems (ILS)	701
Direction Finders (DFs)	203
And More Coming	

I will now conclude my talk with a frank discussion of some of our more pressing concerns.

The first of these concerns is airspace utilization. Capacity and efficiency remain a challenge in our management of navigable airspace. Although better use is being made of this limited resource than ever before, we have yet to take advantage of available options.

An excellent example of this is our inability to fully implement existing concepts, such as Area Navigation (RNAV) and great circle routes. As a result, we have been subject to criticism from users who have made substantial investments in avionics which provide these capabilities.

A second concern is that airspace saturation in major terminal areas will become more severe unless runway acceptance rates can be safely increased. Many possibilities have been examined, including the construction of new airports. This option does not appear viable at most hubs in the foreseeable future because of the high cost of environmental concerns.

These concerns underscore the need to expand the capacity of the existing airports. New metering and spacing techniques must be developed along with techniques to cope with the problem of wake vortices. The highest priority should be given to developing the needed technology to increase runway acceptance rates and, thereby, airport capacity.

In response to our concern about the overall efficiency of the National Airspace System, we are proposing a complete airspace review to begin in the very near future. This review is prompted by the changed aviation demands since our current airspace structure was first established. The following factors were considered in determining the need for this action:

First, the current airspace system has never been systematically reviewed.

Second, there is the recently expressed user and public anxiety over the efficiency and safety of the system.

Third, to reduce our over dependence on foreign energy resources, we must develop a less energy intensive system.

Fourth, the intended use of the airspace by the various user groups has shifted considerably in the recent years. The general aviation aircraft is more numerous and sophisticated, air carrier and commuter operations have greatly increased, and deregulation has increased airspace loading in the low altitude stratum.



Lastly, we must better accommodate military demands for special use airspace and high-speed low altitude training routes.

To accomplish these objectives, we propose the following three phase action plan:

Phase I - A 30 month evaluation of the airspace structure at FL 180 and above.

Phase II - A 48 month evaluation of the airspace structure below FL 180.

Phase III - A final 120 month period during which the following new, programs, systems, and procedures will be integrated into the National Airspace System.

- Discrete Address Beacon System (DABS)/Data Link
- Automatic Traffic Advisory and Resolution Service (ATARS)
- Metering and Spacing
- Automated Flow
- Consolidation of ATC Facilities
- 9020 Replacement and Enhancements
- Reduced Separation Minima
- Area Navigation (RNAV)
- Other R&D Initiatives

Other concerns are in the new facilities and equipment area (F&E Program). Management of our flight service station modernization program is one of our most frustrating challenges. Systemwide, the operation of the FSS is inefficient because we are obligated to operate small facilities instead of using our resources in the larger facilities where demand can more efficiently be met. Our delays in establishing a consistent course for improvement and false starts may have diminished the dedication of our FSS people and adversely affected the users of their service.

Our major automation systems, NAS en route Stage A and ARTS III, have fulfilled all expectations, but near-term modifications and enhancements are needed to keep pace with air traffic growth and increasing user demands until these systems are replaced. Although we have experienced several isolated computer capacity problems at a couple of our sites, they have been effectively resolved through minor software design changes, contrary to self-serving charges by the controllers' union, the number of computer outages in the system has been continually on the decline. Moreover, we consider the present rate of computer outages reasonable in both number and duration and our backup systems fully adequate.

Another of our major concerns and one that involves safety is the

continuing acceptable rate of errors in the system. These errors invariable are the result of improper coordination, lack of coordination, inattention, forgetfulness, or inadequate position relief briefings.

During the five-month period from January to May of this year, there were a total of 247 system errors reported. Although this represents a 7 percent decrease over the same reporting period of last year, it is, nonetheless, unacceptable.

While we have developed and implemented training programs to correct these errors, it is apparent that the human factors element needs more attention in planning system improvements. Towards that end, we are working with the MITRE Corporation to develop programs designed to address this weakness.

Even with better planning, quality control, and management of technology, safety in the system will, in the near-term, continue to rest heavily on the shoulders of the controller and ultimately depend upon the motivation, dedication and competence of our supervisory and controller workforce.

Despite the foregoing, we must be prepared for the possibility of an illegal controllers' strike. To ensure the continuation of ATC service should it occur, we have developed an operational contingency plan. It is an action plan to provide the best service possible using our remaining personnel. While the plan is in effect, our capability will be severely reduced since our facilities will be manned primarily with supervisory personnel. Consequently, ATC operations will also be severely reduced to ensure safety.

The plan provides for transportation of the most people possible and, therefore, preference is given to air carrier and air taxi flights. Long-range flights will be given top priority as alternate travel methods are least acceptable and available for long distances.

Permanent daily schedules will be provided to limit traffic to the capacities that will be available at the facilities servicing these flights. Routes from point to point are predetermined and specific altitudes are assigned to each airway. This was done to provide, to the extent possible, built-in altitude separation, a smooth flow of traffic in all the facilities, and no airborne delays.

The schedules contained in the plan will be based on current airline flight schedules; however, departure time will be altered. All but a minimum number of long-range flights that traverse more than 500 miles will be accommodated. International flight departure and arrival times have been adjusted to the minimum extent possible and all are expected to be accommodated except some serving Canada and Mexico. This approach will ease the air traveler's burden and airport waiting area congestion.

As a result of this plan, airlines will be required to accept routes and altitudes which are far less than desirable. In addition, the predetermined schedules must be followed.

Some other air carrier and air taxi flights will be accommodated but will be restricted to the extent necessary to avoid impacting the long-range flights.

To provide for these basic transportation needs while the plan is in effect, the military will be asked to terminate some training and other noncritical flights. Military necessity or emergency activities will continue to receive top priority and be supported to the extent possible with our limited resources.

All other types of air traffic will be impacted to the extent required to maintain essential services. We anticipate the need to establish special restrictions on general aviation activities and curtail or suspend services at specified tower controlled airports.

The operational contingency plan will also address several other related problems such as probable sabotage, threats or physical harm to nonstriking controllers and supervisors, and special emergency restrictions. These restrictions include disapproval of most VFR flights in terminal control areas, refusal to accept some proposed IFR flight plans and termination of TRSA service.

We will keep the air traffic control system operating safely, serving the critical requirements of the military, emergency flights and most necessary long distance air carrier flights. All other users of the system will be severely impacted.

In conclusion, and on the brighter side, we are confident that our controller intensive system, a factor which is at the heart of most of our system problems, will be increasingly less so intensive in the long-term through automation enhancements. Significant among these are Discrete Address Beacon System (DABS), Automatic Traffic Advisory and Resolution Service (ATARS), and Metering and Spacing.

The introduction of DABS into our ATC System, coupled with its two-way data link and improved ability to discretely identify aircraft, will provide the capability for the introduction of ATARS. ATARS will greatly reduce the midair collision possibility through its cockpit display of proximate aircraft and conflict resolution commands. Eventually, we expect that with the advent of metering and spacing coupled with the data link, we will, in effect, automate today's manual controller vectoring procedure and establish safe and optimum flows of air traffic throughout much of the system.

As these systems are proven and increasingly in use, the controllers role will gradually shift to that of a system manager/monitor rather than the essential element in the system.

Thank you for providing me an opportunity to talk with you today.

I will now conclude my talk with a frank discussion of some of our more pressing concerns.

The first of these concerns is airspace utilization. Capacity and efficiency remain a challenge in our management of navigable airspace. Although better use is being made of this limited resource than ever before, we have yet to take advantage of available options.

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A second concern is that airspace saturation in major terminal areas will become more severe unless runway acceptance rates can be safely increased. Many possibilities have been examined, including the construction of new airports. This option does not appear viable at most hubs in the foreseeable future because of the high cost of environmental concerns.

These concerns underscore the need to expand the capacity of the existing airports. New metering and spacing techniques must be developed along with techniques to cope with the problem of wake vortices. The highest priority should be given to developing the needed technology to increase runway acceptance rates and, thereby, airport capacity.

In response to our concern about the overall efficiency of the National Airspace System, we are proposing a complete airspace review to begin in the very near future. This review is prompted by the changed aviation demands since our current airspace structure was first established. The following factors were considered in determining the need for this action:

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AN OVERVIEW  
of the  
FAA ENGINEERING AND DEVELOPMENT PROGRAM

by  
Robert W. Wedan  
Director, Systems Research and Development Service

The Federal Aviation Administration Engineering and Development program is driven by the need to maintain and enhance the safety of the aviation system, to achieve improved performance of the system for the participants and the flying public, and to make the system more productive--to constrain the cost of the system to the Nation.

The primary driving forces in the SAFETY area are:

- o To improve the FAA air traffic control separation and advisory service and reduce the risk of midair collisions (with a minimum economic and operational burden on the users).
- o To achieve improvements in the air traffic control system and in aircraft operations which take into full account the limits and capabilities of the men and women operating the system.
- o To reduce the number of accidents which occur during the approach and landing phase of aircraft operations.

In the area of PERFORMANCE (Capacity/Delay), the goals are:

- o To achieve a more energy efficient system through reduction of ATC delays and increases in airspace and airport capacity, especially at and near major hub airports where expected increases in operations and enplanements must be accommodated.
- o To reduce the impact of delays due to weather.
- o To improve airport pavement by application of new technology to its design, construction and maintenance.
- o To gain a better understanding of factors such as demand/capacity/delay relationships and the impact of specific improvements in terms of safety effectiveness, real costs, and other benefits.
- o To examine longer range technological alternatives for system improvements and innovation so as to permit evolution to new capabilities in a timely fashion.
- o To reduce negative impacts of aviation on the environment, and to accommodate the impact of aviation activity on landside congestion.

For PRODUCTIVITY, the needs are:

- o To reduce the labor intensiveness of the FAA air traffic control system and the facilities maintenance system by the better use of people and the use of automation.
- o To achieve improvements in FAA's communications, navigation, and surveillance systems and to explore the possibilities of systems integration to achieve a better system at lower costs to both the Government and the users.

#### (VU-GRAPH -- PRESENT PROGRAM FOUNDATIONS)

What are the sources of requirements and objectives for the FAA Engineering and Development program? In summary, they are:

- o Once again, the first is FAA's overall aviation safety priorities.
- o The second are other system performance measures: near-midair collisions, system errors, pilot errors, delays, etc.
- o We draw heavily, of course, on the views and requirements as expressed by FAA's own system operators and regulators.
- o We solicit the views of the user community continually. One way of doing this was through the New Engineering and Development Initiatives process which took place during the 1978-79 time frame, and a large series of valuable perceptions and recommendations was derived from that process.
- o Finally, we are looking ahead to the turn of the century to try to foresee the needs of the system in that time frame, and to tailor our Engineering and Development programs today to meet the requirements of the Year 2000 and beyond. While there are many issues yet to be resolved, we believe that a development roadmap is necessary to assure that we and the community understand the Year 2000 needs and move to meet those needs.

#### (VU-GRAPH -- AVIATION FORECAST CHART)

What is the growth background against which we are working? It can be characterized in many ways, but it may be easiest to say that we expect continued moderate growth in the system over the next 20 years, with quite dramatic changes in the aircraft mix. Even with moderate growth of conventional scheduled air carrier operations, demand is likely to outstrip current capacity. Commuter air carrier operations have grown at the rate of 20 percent a year for the last two years, and we can expect general and business aviation to grow rapidly, with resulting changes in the nature of the system.

FAA programs fall into several categories:

#### (VU-GRAPH -- CURRENT DEVELOPMENT ACTIVITIES)

- o There is a series of development efforts primarily aimed at near-term system improvement. The list of current development activities will give

you a feeling of specific programs of relatively near-term work in the Engineering and Development organization.

(VU-GRAPH -- ADVANCED DEVELOPMENT ACTIVITIES)

- o There are activities in advanced development. Again, there is a group of specific programs.

(VU-GRAPH -- BRIDGING ACTIVITIES)

- o There is a third category of "bridging" efforts that impact current major systems development, advanced development, and system integration.

Let me now try to group this set of programs and efforts into more digestible form. (Each underlined item in what follows represents a specific program area.)

- o A major FAA effort centers around Aircraft Separation Assurance. Within this program are the completed Conflict Alert program and the development of a conflict resolution system.
  - The Discrete Address Beacon System (DABS), which will provide a major improvement in FAA's air traffic control surveillance capability and will make possible automatic digital communications for safety services, is at the heart of the Aircraft Separation Assurance program, as well as a number of other parts of the system evolution

(VU-GRAPH -- DABS/ATARS CONCEPT)

- The DABS system will make possible the Automatic Traffic Advisory and Resolution Service (ATARS)--a ground-based collision prevention system.

(VU-GRAPH -- DATA LINK)

- The DABS data link will provide a series of services beyond ATARS: clearance confirmation, severe weather warnings, accurate information on winds aloft for flow management, and others.

(VU-GRAPH -- ACTIVE BCAS)

(VU-GRAPH -- FULL BCAS)

- The Beacon Collision Avoidance System (BCAS)--an airborne system to provide last ditch protection against collisions--is in a late stage of development after many years of work. The Active BCAS, and later the full-capability BCAS just beginning development, will provide protection particularly in areas where DABS and ATARS services are not available. BCAS may be particularly valuable wherever system errors and blunders are a problem, and where air traffic services may be limited.

The DABS data link will be used to provide coordination and control for BCAS in areas where it cannot function optimally.

(VU-GRAPH -- AUTOMATED TERMINAL SERVICE)  
(VU-GRAPH -- AUTOMATED PILOT ADVISORY SYSTEM)

- Another prospective weapon against midair collisions is the use of automation at the low-activity airport, the airport which may not yet qualify for VFR tower service. Both FAA and NASA have been working in this area, on concepts called Automated Terminal Service (ATS) and Automated Pilot Advisory System (APAS), and a program which will extend these two successful feasibility developments is under consideration at the moment.
- Finally, an effort which grew out of the New Engineering and Development Initiatives activity is called Alternate Separation Concepts. The New E&D Initiatives people felt it important for FAA to examine new ideas by which especially general aviation could achieve certain safety benefits for themselves and in relation to full IFR aircraft, without being full-time participants in the ATC system. An effort is underway, working with the community, to try to put some flesh on those still-bare conceptual bones.

(VU-GRAPH -- DEVELOPMENT ROADMAP FOR  
COMPUTER REPLACEMENT PROGRAM)

- o A second major area is that of the replacement of the air traffic control computer system and the efforts to introduce additional automation into the ATC system. First, and most immediately important, is the program to replace the existing ATC computer system, starting with the en route system and the display suite, with a far more capable, reliable, higher capacity system--one that not only performs current ATC automatic functions well, but which will serve as the foundation for a series of additional automation steps. The knowledge and wisdom FAA can apply to the design and architecture of the computer replacement program will, in large measure, determine the degree and the pace at which further system improvements can be achieved. You will hear more later on about the computer and display replacement program.

(VU-GRAPH -- ETABS)

- o Other work in advanced automation for improved safety and productivity includes the completion of an En Route Minimum Safe Altitude Warning System (EMSAW), the development of electronic tabular displays for both en route and terminal operations, advanced en route automation starting with the en route metering system currently in a late stage of development, the Automated En Route ATC System concept (AERA), and the development of an Integrated Flow Management system which will tie together a series of developments and will use automation tools to help controllers provide optimum terminal airspace and airport utilization while permitting aircraft to operate in a fuel-efficient manner.
- o The FAA Weather program is aimed at severe weather detection, processing, display and communication to pilots. The efforts include a future weather system design which will encompass an improved nationwide Doppler weather (NEXRAD) network to be shared by several U.S. agencies. Efforts to



improve short-term forecasting, work to better show weather on terminal displays, work to provide automatic weather observations both at major airports and very small ones, and developments to permit the use of DABS data link to provide better information to pilots and to draw information from aircraft for flow management, are part of this area.

- o In addition to the weather activities which involve radar services, a task force is underway to examine the future requirement for surveillance--both primary and secondary radar. While there is little question that primary radar will be a long-term requirement for terminal operations, there are some who believe that primary radar should not have a long-term role for target acquisition in the en route system, but that secondary radar should be the primary surveillance source. This is a large and old issue which relates closely to the question of universal carriage of secondary surveillance radar transponders. FAA's effort here is to assess the situation once again and to offer a series of alternatives to top FAA management for consideration.
- o One FAA program area deals with airport capacity and delay problems, noise reduction and fuel conservation. Through the use of workable airport capacity and delay models now completed, FAA/industry task forces have helped FAA draw bottom lines to a series of development efforts. These efforts have helped FAA to pinpoint and concentrate on those improvement areas which can make a significant improvement in airport capacity and reduction of delay. The most important among them are improved traffic flow management through the use of a nationwide Integrated Flow Management System which will use both ground system and aircraft capabilities to create a traffic flow pattern which matches airport capacity to the flow system, which can accommodate airborne area navigation and performance management systems, which can utilize the most efficient safe separation standards, and which can cope with the problems of wind shear and wake vortex.

(VU-GRAPH -- ASDE)

A significant part of this work is the optimization of the airport itself in terms of airport layout, exit design, runway occupancy time control, optimum utilization of short runways for commuters and general aviation aircraft, the successful development of a modern airport surface detection radar (ASDE), automated surface traffic control where this can be justified, and work to improve airport environment and access for passengers.

- o FAA's program to characterize and ameliorate the risk of wind shear has yielded important results. A network of detectors has now been installed. While we have learned a great deal about the wake vortex problems in work conducted by FAA on detection and avoidance of vortices, and NASA has done considerable work on wake vortex alleviation at the source, we have not yet achieved an operationally acceptable wake vortex detection and avoidance system, and work continues.

- o An effort is underway to dramatically enhance FAA programs relating to pilot and controller performance enhancement and error reduction--the area of human factors. A number of activities are underway, and we are working to strengthen this effort in important ways. Among the activities currently in work are efforts to establish cockpit information requirements for the future ATC system; to define improved cockpit alerting, warning, and flight phase monitoring systems; to evaluate the impact of new navigation systems on pilots; to learn more about scientifically objective cockpit workload measurement; and to develop a subjective pilot workload rating scale which includes air traffic control workload.

(VU-GRAPH -- CDTI)

Another part of this effort is the work to determine the benefits and liabilities of Cockpit Displays of Traffic Information, and to provide valid information to regulatory elements of FAA on the capabilities and limitations of Head-Up displays.

(VU-GRAPH -- NADIN)

- o Efforts are underway to improve the vast FAA communications system. Work is underway to characterize a National Data Interchange Network (NADIN), which will provide improved and more cost-effective interchange of FAA's data. This is a critical element in the modernization of the computer system and should permit efficient and cost-effective integration of a variety of services, ranging from the automated flight service stations to communications with remote locations for maintenance data processing. Voice communications programs include the development of modernized communications voice switching systems for air traffic control.

(VU-GRAPH -- MICROWAVE LANDING SYSTEM)  
VU-GRAPH -- FLIGHT SERVICE STATIONS)

- o The completion of the development of the Microwave Landing System is proceeding, as is the development of automated flight service stations to better serve general aviation.

(VU-GRAPH -- FULL SCALE CRASH TEST)

- o There is a major FAA effort on aircraft safety, including fire safety, transport safety, aviation security, and the specific safety problems of general aviation.

(VU-GRAPH -- HELICOPTERS)

- o An important part of FAA's research and development activity concerns helicopters. We are striving to provide for efficient helicopter IFR operations and are working on a variety of services for helicopters and the examination of problem areas, such as helicopter icing.

- o Studies of separation standards with a view to maintaining and assuring safety in an evolving system concerns more than on- and near-airport separation standards. Work is proceeding to examine present standards and to lay the groundwork for improved standards for vertical and lateral separation. Of particular interest to the industry is work we hope to get underway in FY-1981 on reduction of vertical separation from 2,000 ft. above Flight Level 290.
- o Separation standards are also a significant part of FAA's Over-Ocean System Improvement Study, in which an international body is examining the requirements for future operations over oceans and in areas where ATC services are limited.
- o A major effort is underway to examine the navigation system of the future in terms of the requirements of aviation. A DOT/DOD activity is underway which is intended to pave the way for decisionmaking in the late 1982 time frame on the best future navigation capability for the United States. FAA is an active participant and has a series of programs related particularly to establish the present and future capabilities of systems like Loran-C, Omega, the Global Positioning System, and self-contained navigation systems.
- o Closely related to this issue is the question of satellite applications. Satellites remain candidates for operations over oceans and are being examined for that purpose. In addition, efforts are underway to study once again the application of satellite services for aeronautical fixed communications to determine if and when services can be competitive with more conventional land services. Part of this effort is examination of the DABS system to determine whether a version of DABS can be used in a satellite surveillance system--when and if such systems become cost effective.

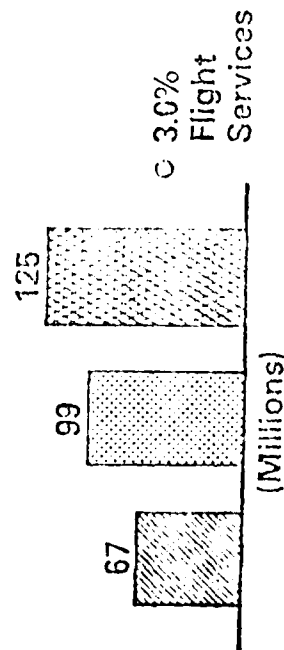
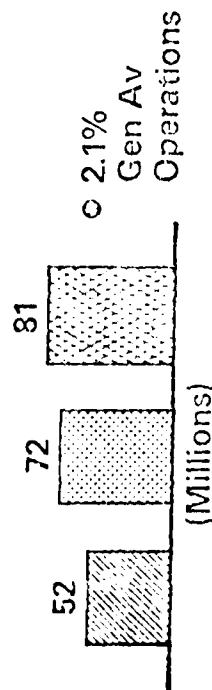
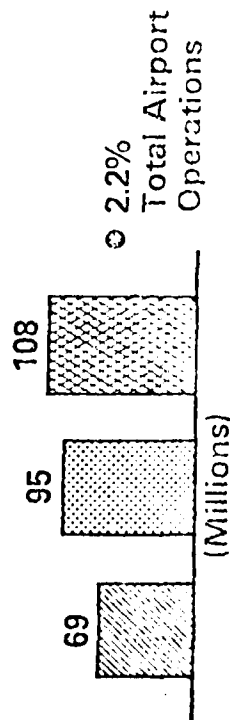
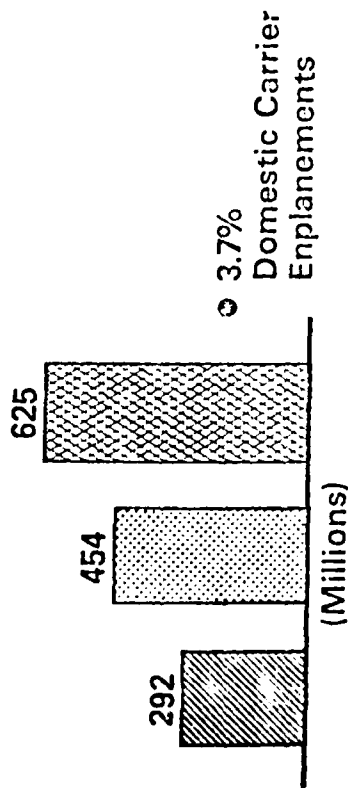
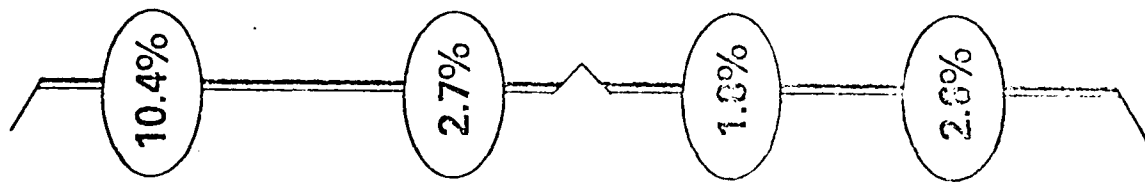
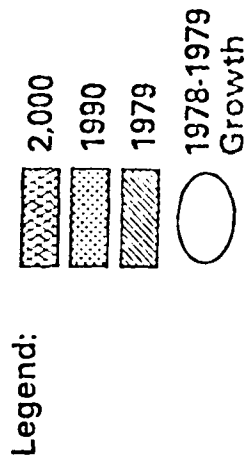
In this brief overview, I have not covered each of the programs, but have tried to give you a picture of what concerns us, and efforts which FAA must press actively to achieve results.

## ***Present Program Foundations***

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- FAA Aviation Safety Priorities
- System Performance Measures
- FAA System Operators
- Users
- New E&D Initiatives Process Recommendations
- Year 2000 Scenario and Development Roadmap

# Aviation is Growing



## System Demand

Enplanements:  
55% Growth by 1990

Operations:  
38% Growth by 1990

More Than Doubles  
for Enplanements  
and Almost Doubles for  
Flight Services by 2000

# ***List of Current Development Activities***

- ◉ **ATC System Improvements**
  - Minimum Safe Altitude Warning (MSAW)
  - Metering and Spacing
  - En Route Metering
  - Digital Displays
  - Terminal Information Display System (TIDS)
  - Electronic Tabular Display System (ETABS)
- ◉ **Aircraft Separation Assurance**
  - Conflict Alert
  - Beacon Collision Avoidance System (BCAS)
  - Automated Traffic Advisory and Resolution Service (ATARS)
- ◉ **Surveillance/Communications**
  - Discrete Address Beacon System (DABS)
  - DABS Data Link
  - National Airspace Data Interchange System (NADIN)
  - Voice Switching Control System
  - Airport Surface Detection Equipment (ASDE-3)
- ◉ **Weather Detection & Dissemination**
  - Weather Radar (Nexrad)
  - Weather Displays
  - Wind Shear
  - Automation
  - Weather Data Processing

# ***List of Current Development Activities***

## ***(Cont'd.)***

- Navigation & Landing Systems
  - OMEGA Evaluation
  - LORAN C Evaluation
  - Satellite Technology
  - Microwave Landing System (MLS)
  - Head-Up Display
  - Cockpit Alerting System
  - Vortex Advisory System
  - Lighting
  - Helicopters
- Flight Services to Pilots
  - FSS Automation
  - Voice Response System
  - Direct User Access
- Airport and Aircraft Safety
  - Pavement
  - Aviation Safety
  - Fire Safety
  - Transport Safety
  - General Aviation Flight Safety

## ***Advanced Development Activities***

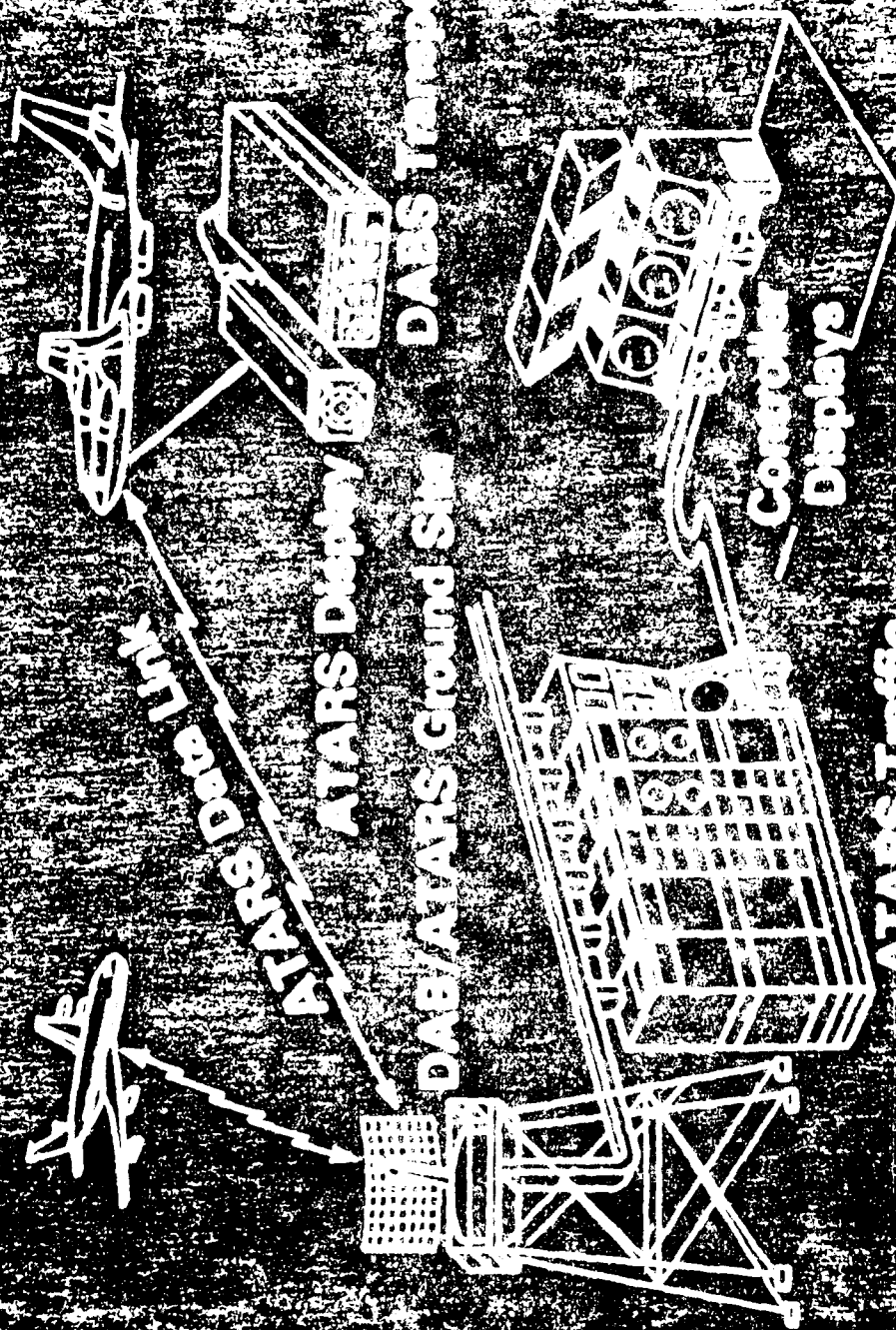
- Long Range Requirements for Advanced Computers
- Automated En Route ATC (AERA)
- Satellite Applications (CONUS-Oceanic)
- NAVSTAR/GPS Receiver Technology Studies
- Cockpit Display of Traffic Information
- Alternative Separation Concepts
- Advanced ATARS Applications Concepts
- Advanced Sensor Technology (Radar, Vortex Detection)
- Advanced Control System Technology (Artificial Intelligence, Fault-Tolerant Systems)
- Automated Airport Advisory Systems



## ***Activities That Bridge Current Major Systems Development and Advanced Systems Development***

- Turn of the Century ATC System Scenario and Roadmap Development
- Aircrew Performance Enhancement and Error Reduction Program
- Controller Performance Enhancement and Error Reduction Program
- Airport and Airspace Capacity/Delay Model Development
- Integrated Flow Management Concept Development
- Use of Separate Short Runways by GA and Commuter
- Innovative IFR Approaches (Triple Parallels, Closely-Spaced Parallels, and Converging IFR Approaches)
- Reduction of Parallel Runway Spacing Requirements
- O'Hare Runway Configuration Management Computer Development
- Vertical, Lateral, Longitudinal Separation Program
- Over-Ocean Improvement Activities
- Airport Landside Capacity and Ground Access Planning Tools

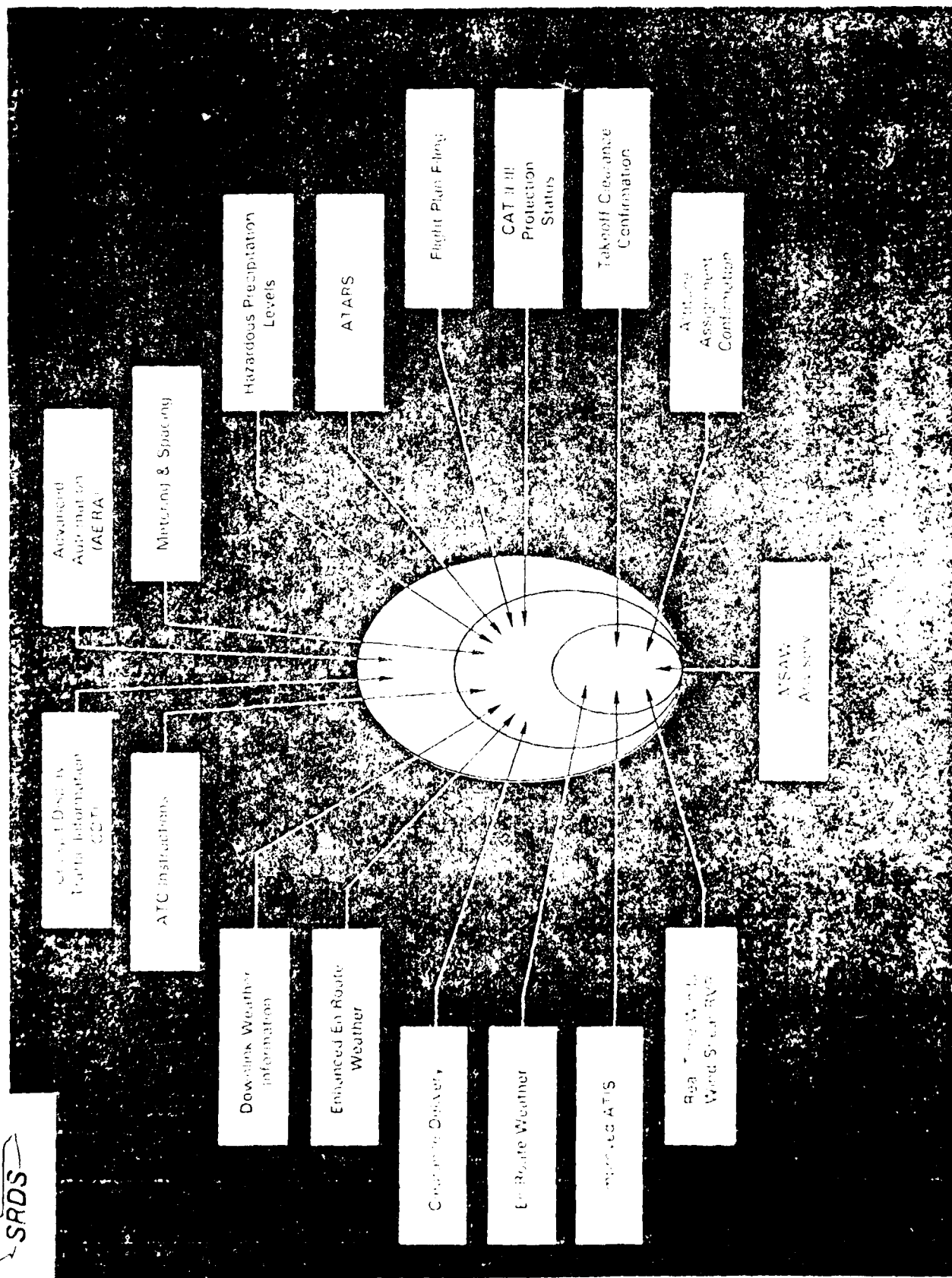
# DABS/ATARS Concept



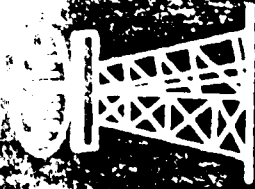
ATARS Traffic  
and Resolution Advisories



# Data Link Services Evolution



# Active BCAS Concept



Ground Station  
(Where Available) for  
BCAS Sensitivity Control

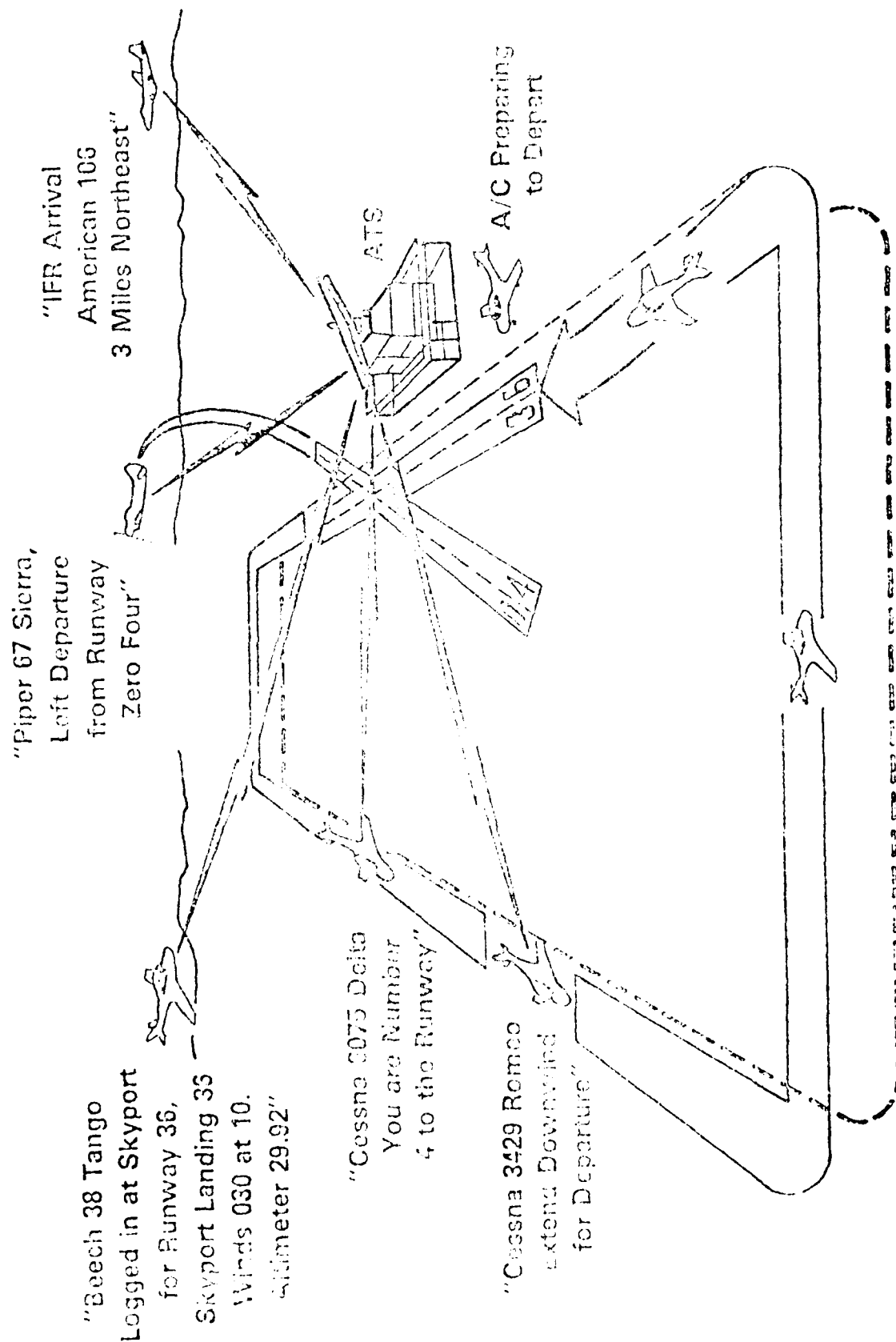
100-100000

WASCO

WASCO

Stations

# Automated Terminal Service



**NASA**

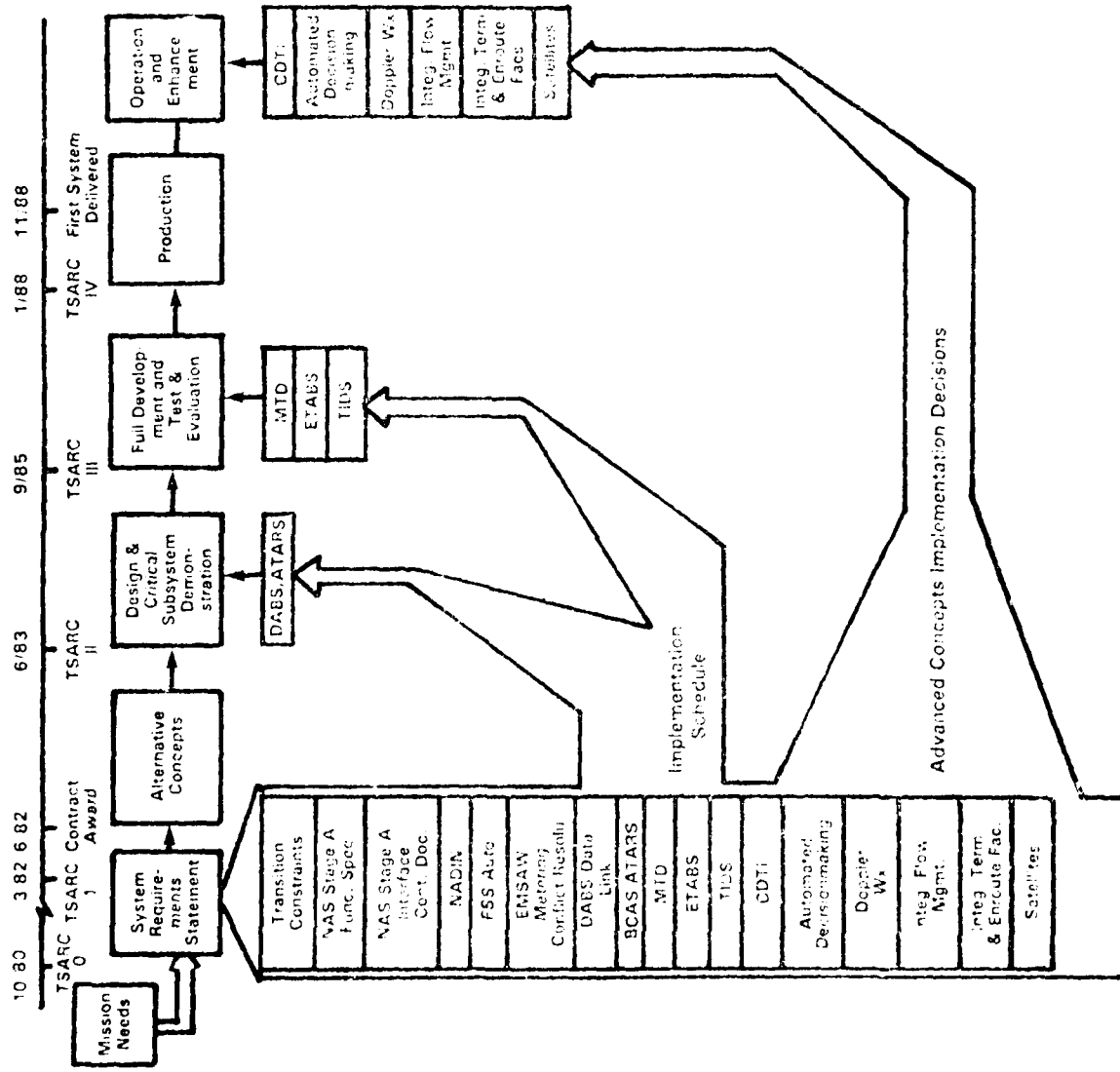
**Safety Research**

**OASD**

**Automatic Pilot Advisory System**



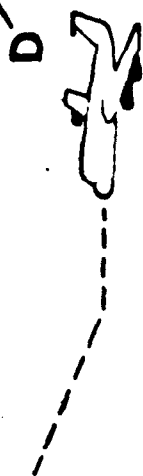
# Federal Aviation Administration Development Roadmap



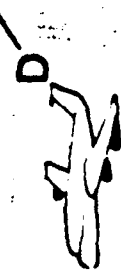


# MSAW

NW123  
010 32



LOW ALT  
NW789  
010 32

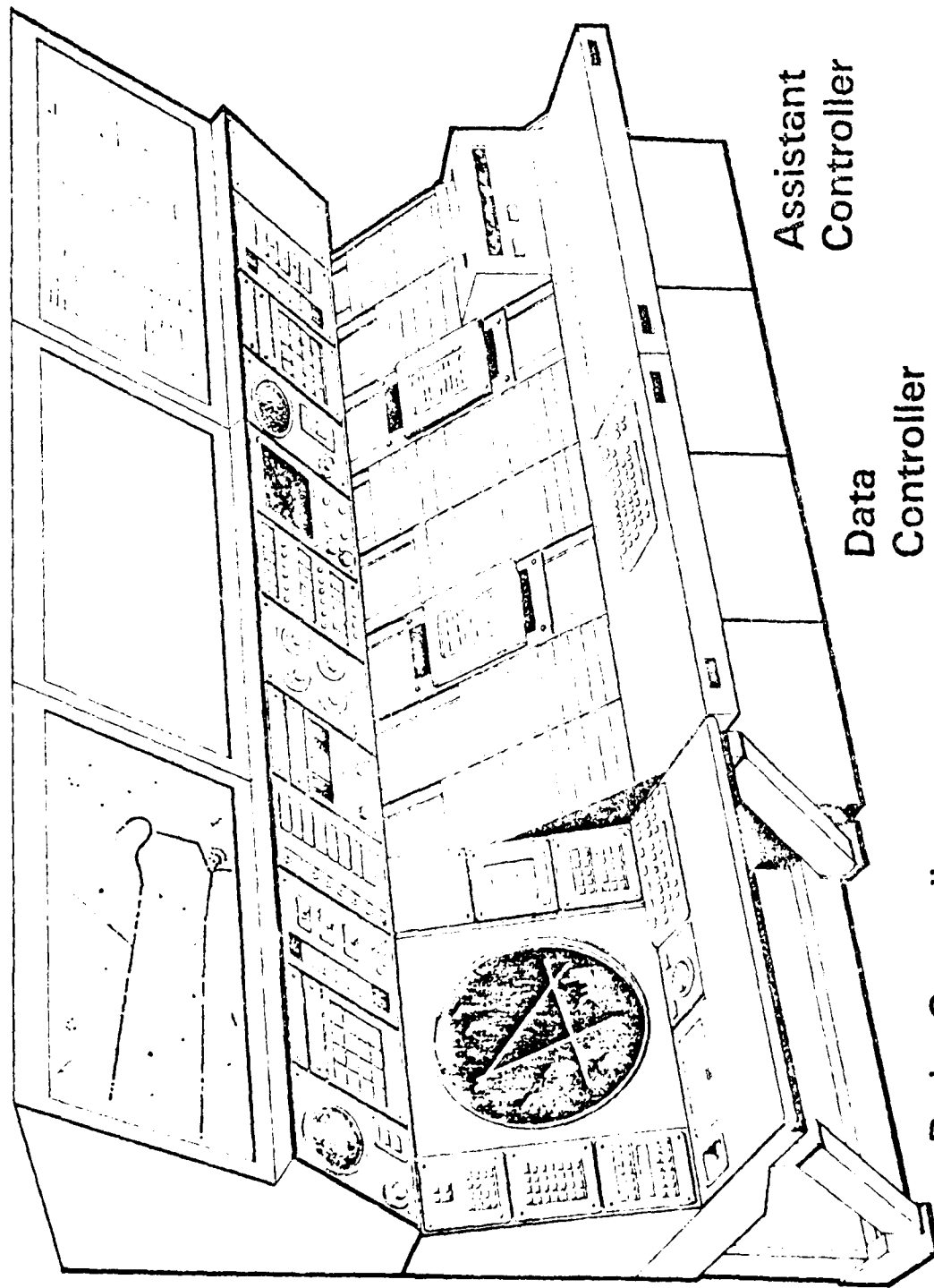


INHB  
PD456  
002 05



SAFETY  
BUFFER

# 1980 Sector Suite



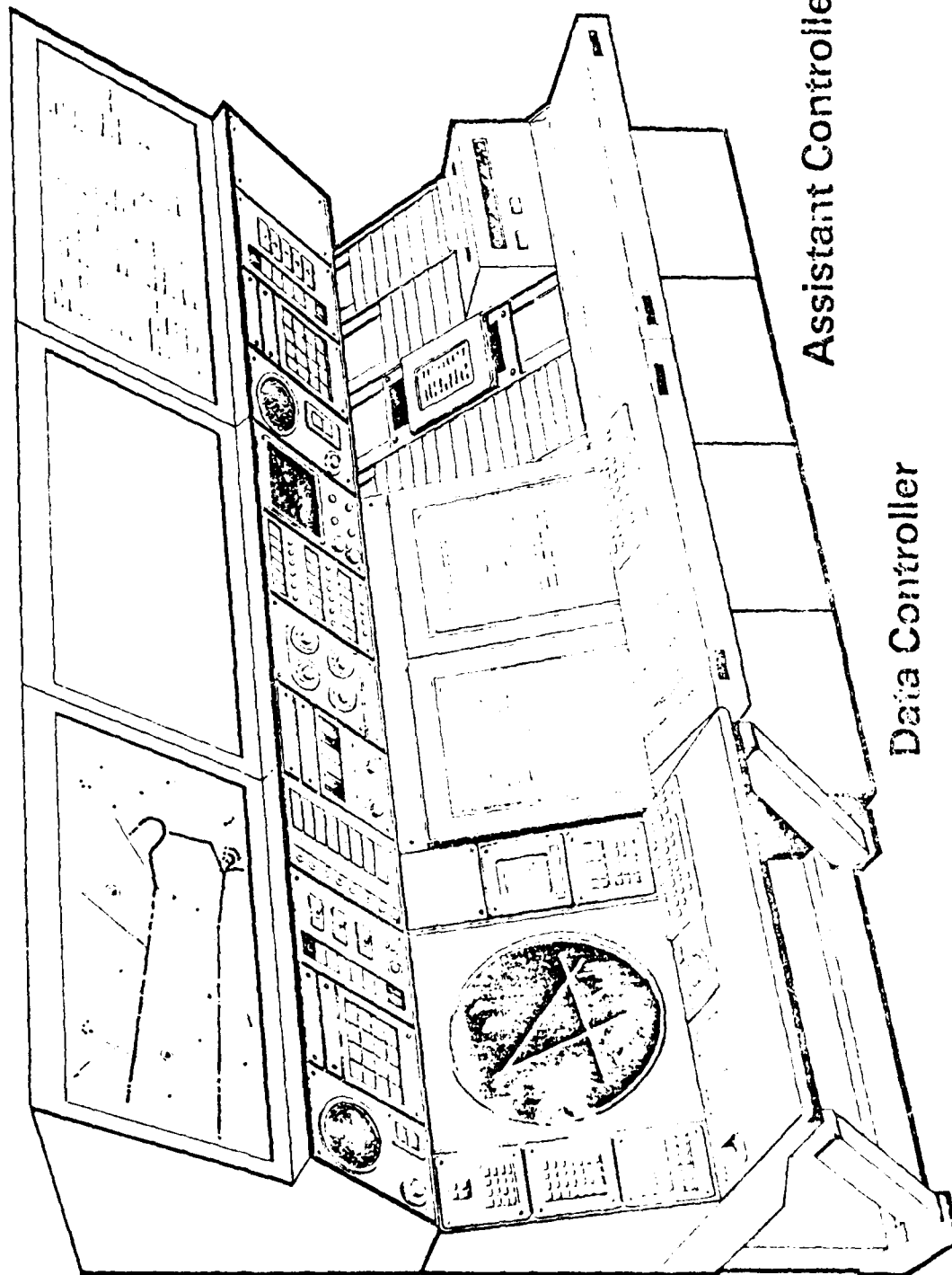
Assistant  
Controller

Data  
Controller

Radar Controller

# **Sector Suite**

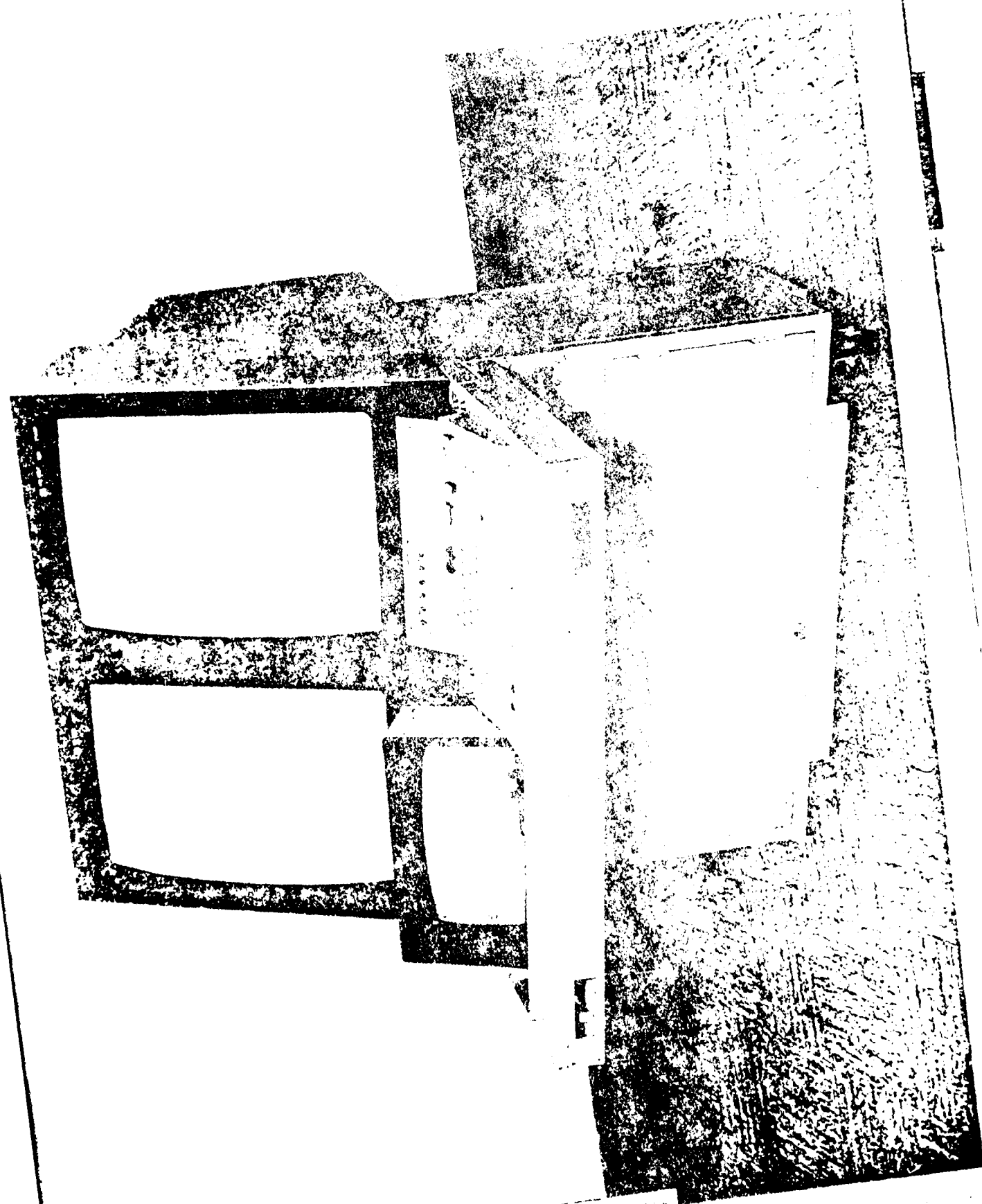
## ***Transition to ETABS***



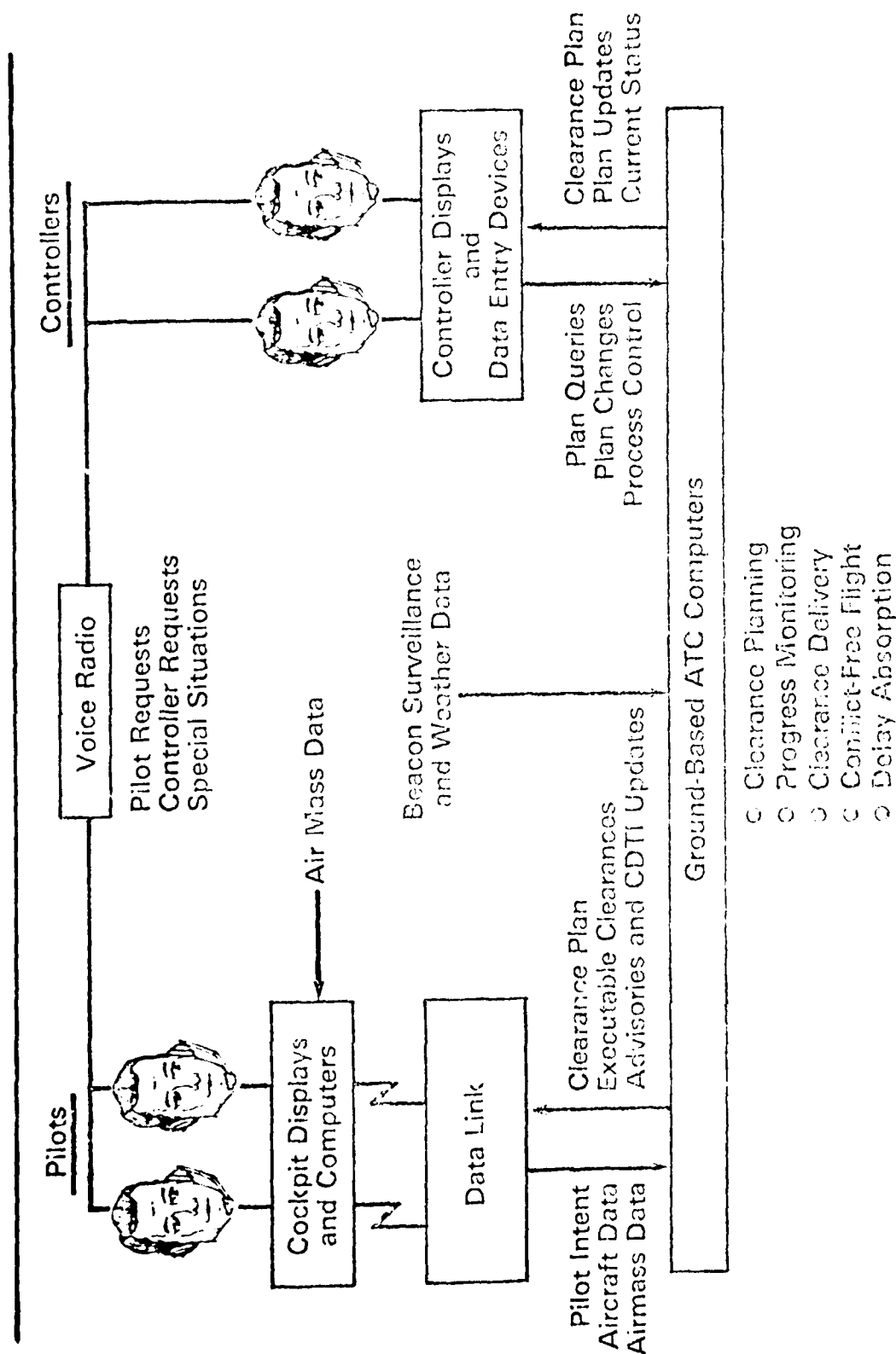
Assistant Controller

Data Controller

Radar Controller



# AERA System Concept



# *Integrated Flow Management*

## **Purpose:**

Integrated Flow Management is a Requirements Definition, Concept Development and Integration Activity. It Will Not Develop Operational Hardware or Software but Will Establish Requirements and Concepts and Evaluate Their Merits and Workability Within the Total ATC System.

## **Objectives:**

- Optimize Aircraft Flow
- Minimize Fuel Burn
- Make Best Use of Capacity
- Maintain or Increase Safety

## **Description and Scope:**

- Develop Functional Concepts for Integrated ATC Planning Aids, Control Tools and Procedures to Expedite and Coordinate Traffic Flow
- Functional Concepts Will Take Cognizance of Other Parallel Activities Potentially Impacting Traffic Flow and Will Be Able to Incorporate Potential for Reduced Separation Made Available by Future Sensors
- Time Frames Addressed for Implementation of Concepts
  - Mid-80's
  - Mid-90's
- Initial Focus is on Terminal/Enroute Interaction

# *Integrated Flow Management*

## Major Areas Addressed

- En Route Metering
- Flight Management Systems/4D RNAV
- Terminal Planning and Configuration Management
- Profile Descents
- Vortex/Wind Shear Detection and Prediction
- Severe Weather
- MLS Procedures
- Airport Surface Monitoring and Control
- Terminal Metering and Spacing
- Data Link

## Initial Areas of Activity

- Concept for ATC Accommodation of Flight Management Systems. Impact on Automation Aids and Procedures to Best Meet Preceding IFM Objectives
- Studies of Traffic Flow at Major Hubs to Evaluate Applicability of Improved Automated Planning and Control in Meeting IFM Objectives.
- Evaluation of Various Concepts for integration of Enroute Metering, Terminal Metering and Spacing in a Mixed Environment to Take into Account Accommodation of Runway Reversals, Vortices, Mixed Approaches and Mixed Aircraft Equipage.





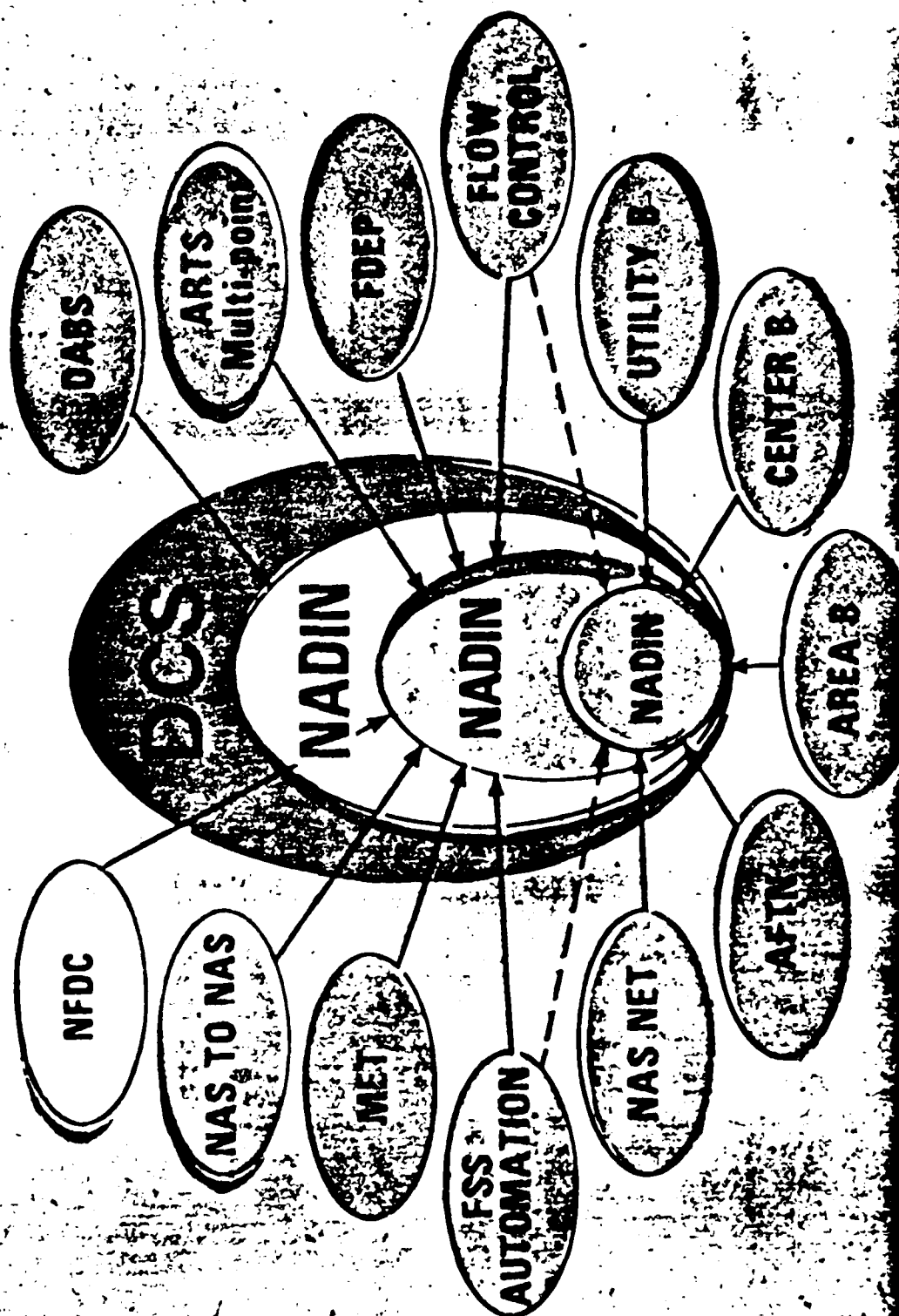
# COCKPIT DISPLAY OF TRAFFIC INFORMATION

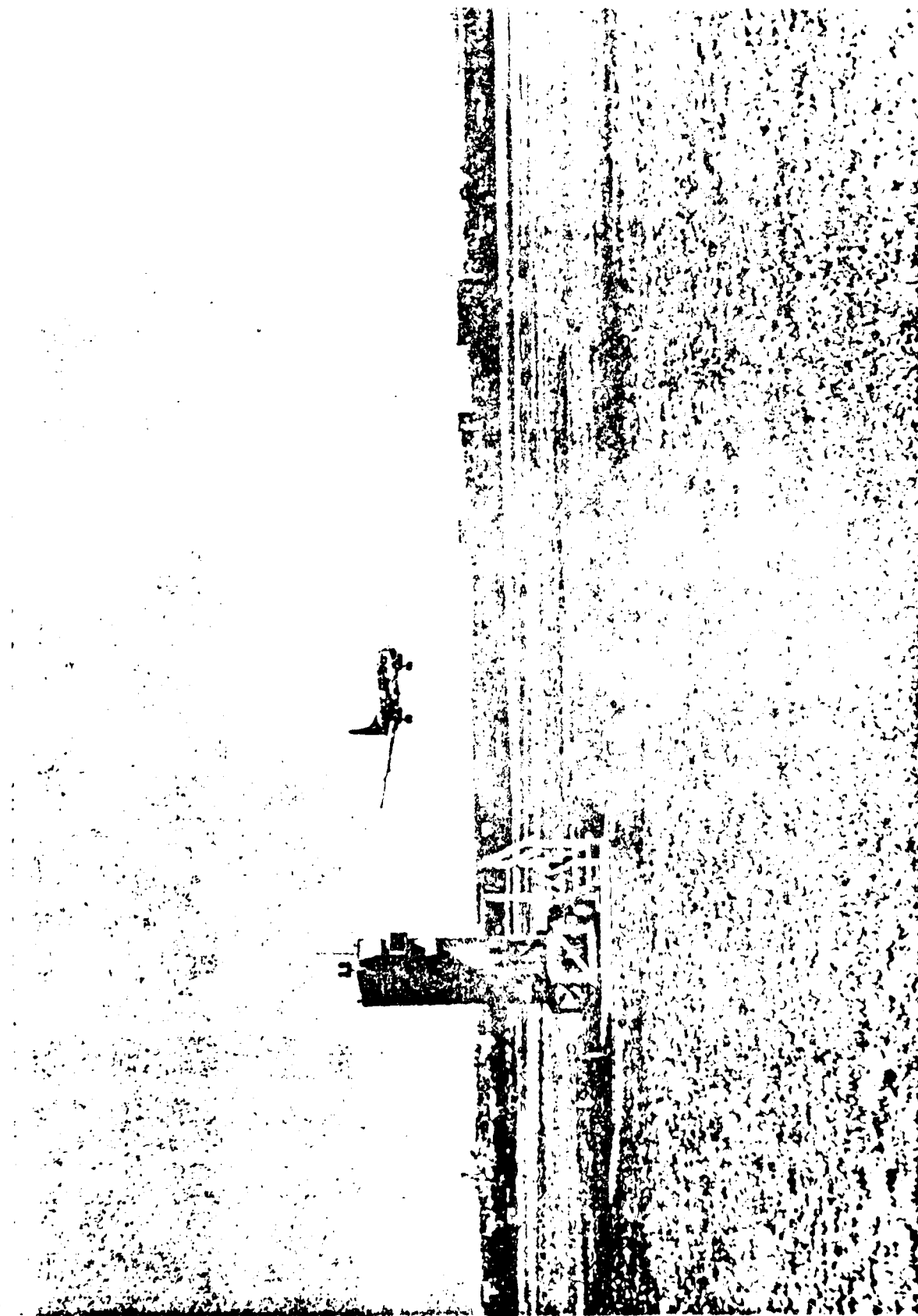


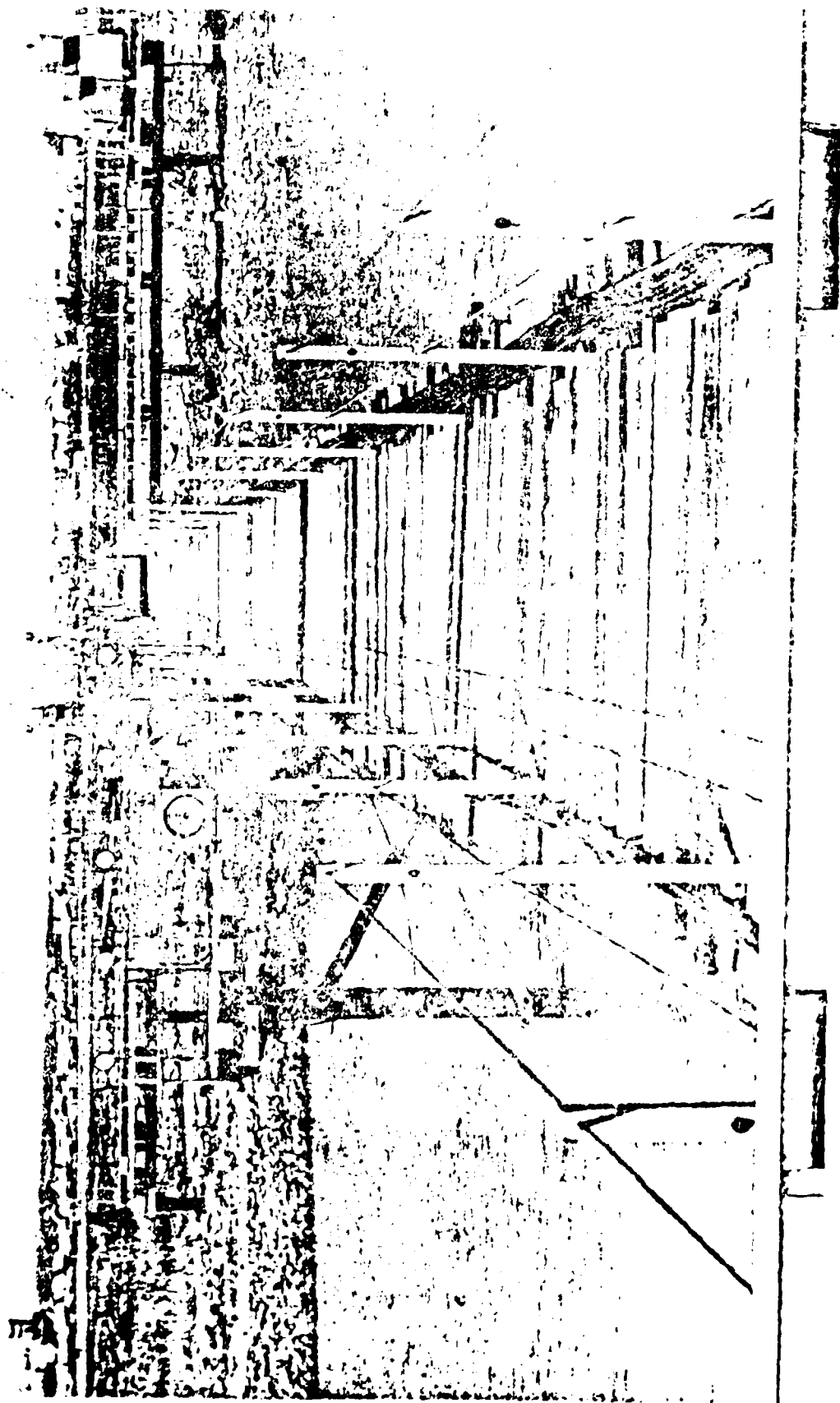
COCKPIT DISPLAY

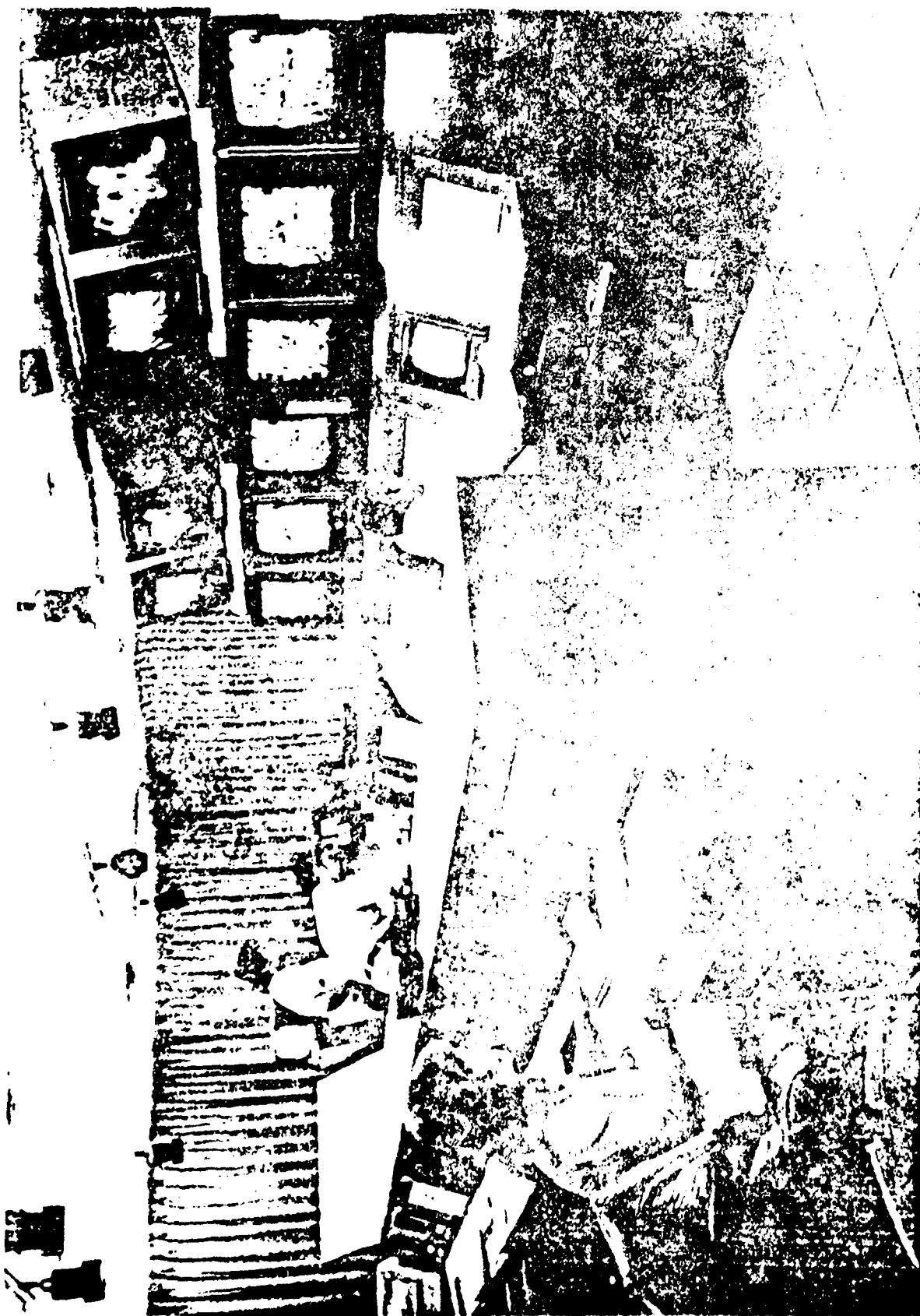
COCKPIT DISPLAY

# INTERRELATION OF SYSTEM & CONCEPT





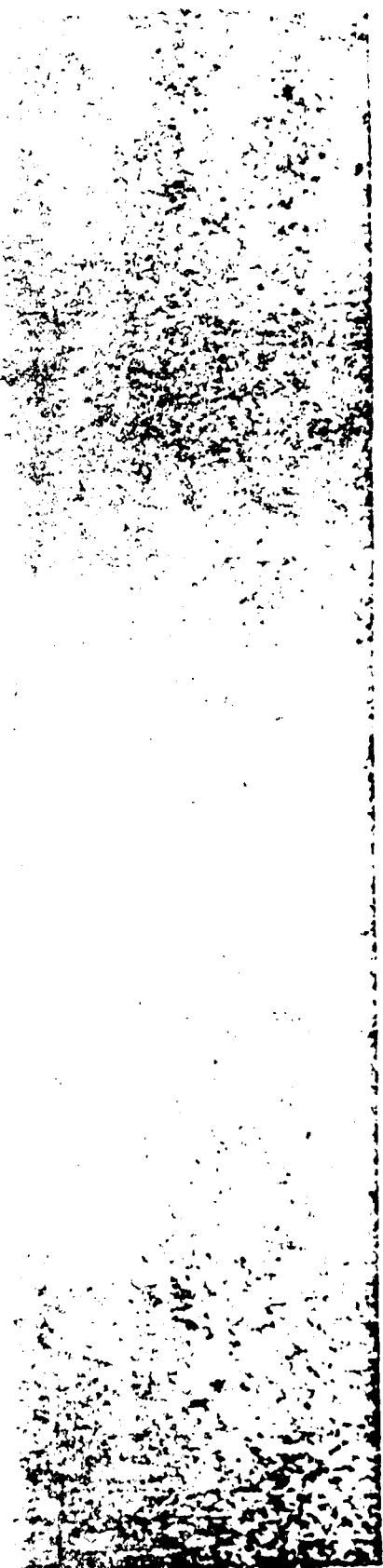
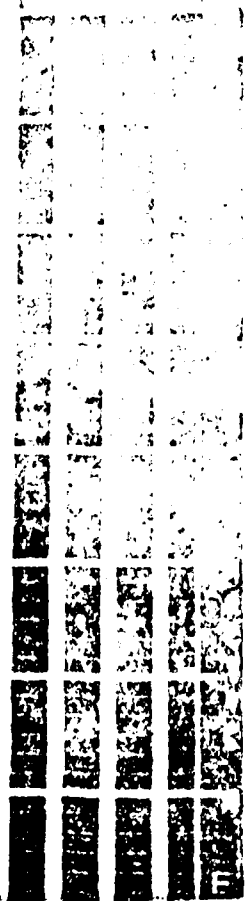








AD-1



## SCENARIO FOR THE FUTURE SYSTEM

by  
Siegbert B. Poritzky  
Director, Office of Systems Engineering Management

It is important to understand where FAA's E&D program is leading. What can we expect? What development and implementation must be started now to meet the demands of what we continue to believe will be a growing system?

FAA has just completed an effort called, "New Engineering and Development Initiatives--Policy and Technology Choices," in which we invited all elements of the aviation community to join us in examining the problems of the present and the future, and to offer candid recommendations on the way to go from here. We found this process valuable, not because revolutionary new ideas emerged, but because both FAA and the aviation community gained a better understanding of each other's problems. The community provided a series of insights and recommendations which are influencing our development effort for the future.

Using the recommendations from the user community and our own work, FAA has undertaken to postulate the system as we believe it can and should work around the turn-of-the-century. FAA has looked at the problem from an Operations vantage point, as well as an assessment of expected technology and the possible evolution of aircraft and aviation community.

I would like to briefly discuss a summary of that thinking. It will undoubtedly change, but we think that this work will help us create a roadmap of development and implementation to achieve the capabilities we feel will be essential for the future. Let me begin with some precepts for the future ATC system design.

- o No change of the system will be permitted to reduce safety. On the contrary, new systems or procedures will be judged on the increase in safety to be gained.
- o Changes to the system will occur in an evolutionary way whenever possible. However, as system needs change in the future, no decision can necessarily be permanent or final. Sufficient flexibility must be maintained to accommodate revolutionary changes, if necessary.
- o Traffic levels will rise at approximately the currently projected levels. No artificial constraints will be assumed. Even if there is less growth than predicted due to rising fuel costs, increases in basic system capacity must be achieved to insure the absolute minimum of system delays.
- o A very high level of protection against midair collisions must be provided by the FAA system. The techniques for providing this protection, as well as aircraft equipage requirements, will vary depending upon the nature and density of air traffic activity. However, in order to maintain the



highest level of freedom of the airspace, "see-and-be-seen" operations under visual meteorological conditions will be available where possible.

- o In some airspace, services will be provided by an essentially fully automatic ground-based system coupled with airborne automation systems, and will be the only services available. However, all properly equipped users will have access to the system.
- o There will be airspace where no ATC services are provided and none are required.
- o Automation of the Air Traffic Control system will be pursued wherever it increases safety, productivity or efficiency.
- o There may be shifts in the balance of control responsibility between pilots and controllers.
- o Only relatively little growth in the number of major airports can be assumed at this time, though it is recognized that major increases in capacity can only be achieved by addition of new runways and new airports, and by raising IFR capacity to VFR capacity levels. Continued emphasis on FAA's satellite airport program will offer capacity increases, but will not be a substitute for new runways and new airports.
- o We perceive an ever-changing mix of air traffic, including a significant rise in the number of commuter operations, general aviation, helicopters, and business aviation aircraft.
- o The Air Traffic Control system in the year 2000 and beyond will continue to be an integrated system that accommodates both civilian aircraft and military air traffic.
- o Energy conservation will become an increasingly critical factor impacting the design of various Air Traffic Control programs.
- o Finally, provisions for special use airspace will continue.

In postulating the system of the future, we have had to make a series of assumptions which are based on our best current thinking:

- o One is that a great deal more automation of the air traffic control process can be achieved, and that our computer systems and their safety back-ups can be designed in such a way that automated decisionmaking and automated clearance generation will be possible and acceptable. We have learned a lot since the romantic notions of the 1950's that automation was around the corner and that the whole process would become automatic. Yet, if we are to provide a high level of flexibility in aircraft operations and permit conservative fuel use, we believe the task of air traffic control--that of traffic separation and efficient flow management--will require juggling more variables than can be done successfully by human controller teams alone.

- o Our second assumption is that it may be practical to place more responsibility into the cockpit, since technology advances and a better understanding of human factors may offer the potential for redistribution of certain responsibilities between the ground and airborne portions of the system. These changes may involve additional pilot responsibility for separation in addition to the navigation and clearance execution functions, without additional total workload. They may also include airborne devices which permit a higher level of self-separation in certain airspace, automatically coordinated with the ground-based air traffic control separation service.
- o Third, we have assumed that the primary air traffic control surveillance system of the future will be the Discrete Address Beacon System (DABS), and that while the navigation system is not likely to change dramatically in coming years, especially in a domestic environment, new systems such as the Global Positioning System (GPS) may come into use in some airspace.
- o Users have an intrinsic right of access to the system. Limitations or restrictions will be imposed only when no other recourse is available. They will be removed as soon as possible.
- o Finally, we are mindful of the potential attractions of additional satellite services and "space radars." These new tools can be accommodated in the system when they prove capable and cost-effective.

So much for assumptions of future capability.

We believe there will continue to be several levels of air traffic control service in the United States, ranging from a highly automated system serving fully participating aircraft in certain airspace, all the way to airspace in which no separation service is provided.

The basic air traffic control separation service will continue to be a ground-based service based on knowledge of current aircraft position and intent. Ground control and flow management will remain important in en route airspace to assure fuel-efficient flight paths and to handle rerouting due to weather. It will remain critical in major terminal areas and in adjacent transition airspace to optimize airport efficiency and aircraft fuel efficiency, while protecting against collisions.

In the first level of service, applicable to airspace where there is full participation in ATC services and in major terminal areas, the highest level of automation will be employed to support the separation service. The control system will be designed to offer very high reliability and reversion capability to a safe, back-up automatic control system. Reliability of the automated system will be achieved by top-down redundancy at individual control facilities and facility-to-facility backup using a flexible data communications network. The automated system will be backed-up automatically by the DABS/ATARS system which will independently provide information directly to the cockpit and to controllers. Another level of protection, which may also serve to build confidence in automation, may be achieved by use of cockpit traffic displays utilizing the DABS data link and/or an independent BCAS. Flexible

use of area navigation and an automated ground-based system capable of handling large numbers of variables will allow a high degree of routing freedom, both laterally and vertically. Our work on Automatic En Route ATC systems, called AERA, will serve as the basis for this system. We believe that even in this airspace, some degree of self-separation may be possible if traffic information can be provided to the cockpit in such a way that aircraft are aware moment-to-moment of the position and perhaps the intent of other aircraft, and that procedures can be worked out to assure that pilots' and controllers' actions are fully understood and coordinated.

In the second level of service, provided in low and medium-density traffic areas with mixed IFR/VFR operations, the service will be similar to the present system, but with automated tools such as metering, sequencing, conflict alert, and conflict resolution advisories assisting the controller. All aircraft in this service level, as in the first service level, will carry altitude-reporting DABS transponders to permit DABS/ATARS and BCAS to operate effectively with the ground-based separation service. Although IFR aircraft equipped with suitable area navigation systems will be less constrained than in today's system, route freedom is likely to be more limited than in a more automated environment. Self-separation by pilots, with the knowledge of the controller, may be available to aircraft equipped with suitable traffic information displays, but direct ground control of the system is likely to be required in terminal areas.

In the third level of service, IFR operations under Instrument Meteorological Conditions (IMC) will be permitted on the basis of procedural rules in a manner similar to that currently employed under non-radar procedures. This service will be available to provide some degree of control to protect aircraft in areas where there is a limited number of aircraft on IFR flight plans. Depending on the level of collision risk to public transportation aircraft on flight plans, aircraft will carry altitude-reporting DABS transponders to allow BCAS or automatic DABS/ATARS services in areas where surveillance service is available to provide separation. Self-separation may be common in this airspace in IMC to the extent that it can be achieved through the use of on-board or ground-based surveillance, a data link, and display of traffic of concern in equipped aircraft.

RNAV-equipped aircraft will have great freedom in the choice of routes for en route navigation, limited only by airspace protection requirements for aircraft on IFR flight plans and restricted airspace.

To some extent, and in certain geographic areas, there is an increase in freedom of choice in selecting air routes today. An increase in this freedom can be expected to coincide with implementation of the programs discussed above.

In the fourth level of service, no separation services would be provided by ATC, but airborne collision avoidance systems may offer a level of protection in addition to "see-and-be-seen."

Perhaps the most precious aviation resource is the airport itself. Several major airports are nearing saturation, and others are expected to approach

saturation in coming years. It is difficult to predict when a significant number of new major airports will be in operation in the United States, and here we come up against a very difficult problem. While we have made important strides in increasing airport and terminal area capacity, there are no miracles waiting in the wings which will dramatically increase capacity of our existing airports. We must anticipate that the demand will outstrip the capabilities of the technology.

Real-time knowledge of actual airport capacity and use of automated runway configuration management systems will permit the use of optimum airport configurations and scheduling of arrivals and departures to achieve limited capacity gains. Better control of the runway itself through reduction of runway occupancy time will allow certain capacity increases. The wake vortex problem will continue to affect airport capacity.

Reduced interarrival spacings may be achieved by reducing deviation in the time of arrival over threshold--probably by extensive use of airborne flight management systems, by wake vortex alleviation schemes or full-time workable ground-based wake vortex sensing and avoidance systems if those can be achieved, by real-time runway occupancy monitoring and control, airport surface surveillance, and possibly runway/taxiway guidance and control systems at the largest airports. An important caution here: Ten years of work have not yet produced a workable solution to the wake vortex problem, and it remains a serious brake on capacity. Work on this problem must continue.

A variety of remedies such as the use of short, staggered and dual-lane multiple runway combinations, along with carefully defined precision approach paths and missed approach paths, will be necessary to minimize wake vortex impact, to accommodate growing traffic, and to permit separate and independent operations from long and short runways at major airports. The use of appropriate airport surface surveillance, area navigation computers, the Microwave Landing System, and perhaps cockpit traffic displays will permit the use of independent closely spaced parallel runways, possibly to a spacing of 2500 feet.

A significant element in attaining optimum airport capacity to major terminal complexes will be a flow management system which, starting in en route airspace, will provide for optimum feeding of traffic in the most expeditious fuel-effective manner. The flow management system, which integrates the functions of national flow management, en route metering and terminal flow, will use automation tools to accommodate the best possible integration of a variety of capabilities. These will include optimum fuel-efficient flight paths, the capability of 3D and 4D area navigation, adequate wake vortex protection and an optimum metering, sequencing and spacing system.

Long-term information regarding weather systems and terminal and capacity information will emanate from many places for national coordination. The flow management service will not evolve into a closed-loop automatic control system including aircraft management or throttle management, but will evolve into one which provides automatic instructions to aircraft which can be executed either automatically or manually in the aircraft to maintain optimum runway feeding while allowing maximum freedom of flight profile selection to pilots of properly equipped aircraft.

We think that a 3D or 4D navigation management computer will become the heart of many aircraft navigation systems. This will make navigation less route-oriented and will let the navigation computer select different navigation sensors for various phases of flight. VOR/DME and perhaps increased use of DME/DME will remain basic to the system for many years, although we look to increased use of other navigation services. We expect to see major improvements in inertial navigation capabilities with important reductions in the cost of ownership, and we expect to see continued use of OMEGA, some limited use of Loran-C, and possibly NAVSTAR/GPS if the goals for that system can be attained. We are currently engaged in an extensive study to examine the navigation system of the future.

The Microwave Landing System will substantially replace the current Instrument Landing System. Precision departure and missed approach paths will be in wide use to achieve optimum departure capacity, and curved and segmented approaches will be used for efficient operations, noise control and selection of paths free from the effects of wake vortices.

There will be important changes and improvements in the weather service. The bulk of weather information used in air traffic control will be obtained from a National weather network and fed to FAA facilities. Primary radar will be used predominantly as a source of weather information. Some air-derived weather data will also be fed automatically to FAA facilities for processing and distribution. Substantially improved weather detection capabilities in FAA terminal radars will be explored. We hope and expect that the application of new technologies such as Doppler weather radar and laser technologies will enable the provision of terminal data concerning severe weather, accurate winds aloft, wind shear frontal movement, wake vortices, visibility, cloud cover and other atmospheric phenomena. Although services will continue to be available in flight through voice channels, weather information will be relayed automatically to aircraft equipped with data link terminals and displays.

The improvement of operations over oceans is the aim of an international group which is reviewing the application of satellites and other techniques to civil aviation. This group is currently in the process of examining improvement options based on an extensive study of current and anticipated traffic.

Safety and efficiency are the primary considerations in this work. The following are improvement options which appear to show the highest promise:

- o Reduction in vertical separation minima above Flight Level 290.
- o Reduction of communications delays and application of automatic dependent surveillance and direct pilot/controller communications.
- o A separation assurance device, such as an Active BCAS, may be an efficient "tail cutter" of the tails of position deviation distribution in relatively high-density over-ocean traffic, and serve as a safety aid in areas of the world where air traffic control services are not well developed.
- o Improvements in inter-facility communications and optimization of control procedures.

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THE FAA PLANS AND PROGRAMS FOR THE FUTURE AIRPORT AND AIR TRAFF--ETC(U)  
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## THE ROADMAP TO THE SYSTEM OF THE FUTURE

by  
Siegbert B. Poritzky  
Director, Office of Systems Engineering Management

### (VU-GRAPH #1 - CAPABILITIES OF THE ATC SYSTEM AT THE TURN OF THE CENTURY)

I would like now to discuss the roadmap, or transition, from where we are today and what we are doing today to the situation in which the services described in this scenario are available. Let's look at a top-level summary of the expected capabilities of the ATC system of the turn of the century, and keep that in mind as we translate it into the services which are implied by it.

### (VU-GRAPH #2 - ATC SYSTEM SERVICES)

Let's look at the services which are required to achieve these capabilities. A series of services are now provided by the air traffic control system. These are at the top of the list. Added to it are additional or new services which are either in development or which will need to be developed in order to achieve the capabilities implied by the Year 2000 scenario. Not all of these are certain, and several will require future assessments and future decisions.

These services will require the development and then implementation of tools to accomplish the job.

### (VU-GRAPH #3 - THE TOOLS)

Once again, the vu-graph shows at the top the tools which are currently in use. Then the tools which must be developed and implemented; and again, there are questions which must be resolved.

The development of these tools must be completed and their implementation must proceed if the capabilities described in the scenario are to be achieved.

But that's not enough, because if the system is to be productive and manpower-efficient, many of these services will need to be integrated and automated.

### (VU-GRAPH #4 - INTEGRATION CONCEPTS AND SYSTEMS)

The vu-graph shows three efforts to create that integration and to create automation which will permit these tools to be used effectively.

- o First is a National Integrated Flow Management System--in effect, an improvement of existing Central Flow with better weather information, with better information on terminal capabilities and better tools to manage and meter the flow where that is essential.
- o Second, and in a way a subset of the first, is Terminal Integrated Flow Management--a concept that pulls together with automation a whole series of terminal tools and capabilities--ranging all the way from optimum en route and transition flow metering and sequencing through terminal metering and sequencing, adaptive wake vortex spacing to airport surface management, and including the best balance between achieving optimum airport throughput and optimum fuel performance for participating aircraft, airport configuration management aids and best integration of new aircraft capabilities into the flow system.
- o Finally--AERA--which, in its simplest terms, is automated air traffic control to provide conflict-free direct routings automatically communicated to aircraft. Initially planned for en route operations, it will be an automatic system which accepts and provides flow information, incorporates weather data and, for the first time, incorporates substantial automated decisionmaking into the computer system. It is here that major productivity gains should be achievable.

These three integrating functions are essential elements in achieving the capabilities of the future scenario.

#### (VU-GRAPH #5 - THE FLOW TO THE NEW CAPABILITIES)

We now identified a series of capabilities, services, and tools; and integration processes to make optimum use of those tools.

It is not hard to see that certain tools represent a core requirement.

#### (VU-GRAPH #6 - CORE TOOLS REQUIRED)

Perhaps the most important, aside from the massive new computer data processing needs I'll come to in a moment, are the Discrete Address Beacon System and its data link, the elements of the improved Weather service, and improved and integrated voice and data communications systems. Without them, the prospects for achieving the desired capabilities evaporate.

But there is perhaps an even more important bottom line.

#### (VU-GRAPH #7 - CURRENT ATC SYSTEM SERVICES INVOLVING COMPUTER DATA PROCESSING)

Looking back at the services, recall that the ones shown on top represent essentially the total capability of the existing en route and terminal



computer systems--the 9020 and ARTS systems. Adding even very limited additional services to those computers will be extremely difficult, if not impossible. Some of the tools can be developed by external add-on processors--but our studies show that this is not only very difficult, but likely to be extremely expensive. It is certain that many of the functions will require a new, highly capable computer system for both en route and terminal applications.

#### (VU-GRAPH #8 - THE ROLE OF THE NEW COMPUTER SYSTEM)

The requirement is therefore for a replacement of the 9020 and the ARTS systems, architecturally capable of evolving to the full services described in the scenario, with sufficient flexibility to permit later options to be exercised with respect to future new communications and surveillance systems, changes in philosophy on self-separation, and a number of other capabilities. The new system must have a level of reliability and availability and an internal structure to accept the AERA functions as they will evolve and the automation elements of the Integrated Flow Management system in a way that we can be confident that real automation of the system--automated decisionmaking functions--can be achieved.

If we do not proceed smartly with the development of that new, more capable computer system, once again the possibility of achieving the capabilities in the scenario evaporates.

#### (VU-GRAPH #9 - A ROUGH TIMESCALE)

There is finally the question of timing of the completion of development of the tools to achieve the capabilities we have been discussing. We are at work to try to build the details of the roadmap to show the way the timing must interlock, if the developments are to come together wisely for implementation.

On this vu-graph, we have shown time bands which represent the time we hope to have initial operational capability of the necessary tools. This is a preliminary assessment, which will be refined over the next several months.

It points up the amount of work to be done, and the need to move rapidly on a number of the major program efforts.

A good many of these dates depend on the successful outcome of research and development--some of which probes new territory. It depends also on steady and consistent funding for R&D activities. It depends finally on decisions and choices yet to be made in several important areas, and that brings us to the discussion of alternative approaches and their impact on the development of the future system.

# ***Capabilities of the ATC System at the Turn of the Century***

Reduced Collision Risk  
Improved Real-Time Weather Service and Flight Services  
Aircraft Design Improvements  
Improved Ground-Ground and Ground-Air Communications  
Design Optimization for Best Human Performance  
Fuel Optimal Direct Routings  
Fuel Optimal Approaches and Departures  
Essentially "All Weather" Operations  
Optimized Airport Throughput  
Minimized Runway Occupancy Time and Airport Surface Management  
More Accurate Position Trend and Altitude Information  
Improved Navigation Service  
Self-Separation Where Applicable  
More Effective and Productive Utilization of Controller Workforce Through Automated  
ATC Decisionmaking  
Centralized Maintenance Concepts for More Effective and Productive Utilization of  
Maintenance Workforce  
Essentially 100% System Availability and Reliability

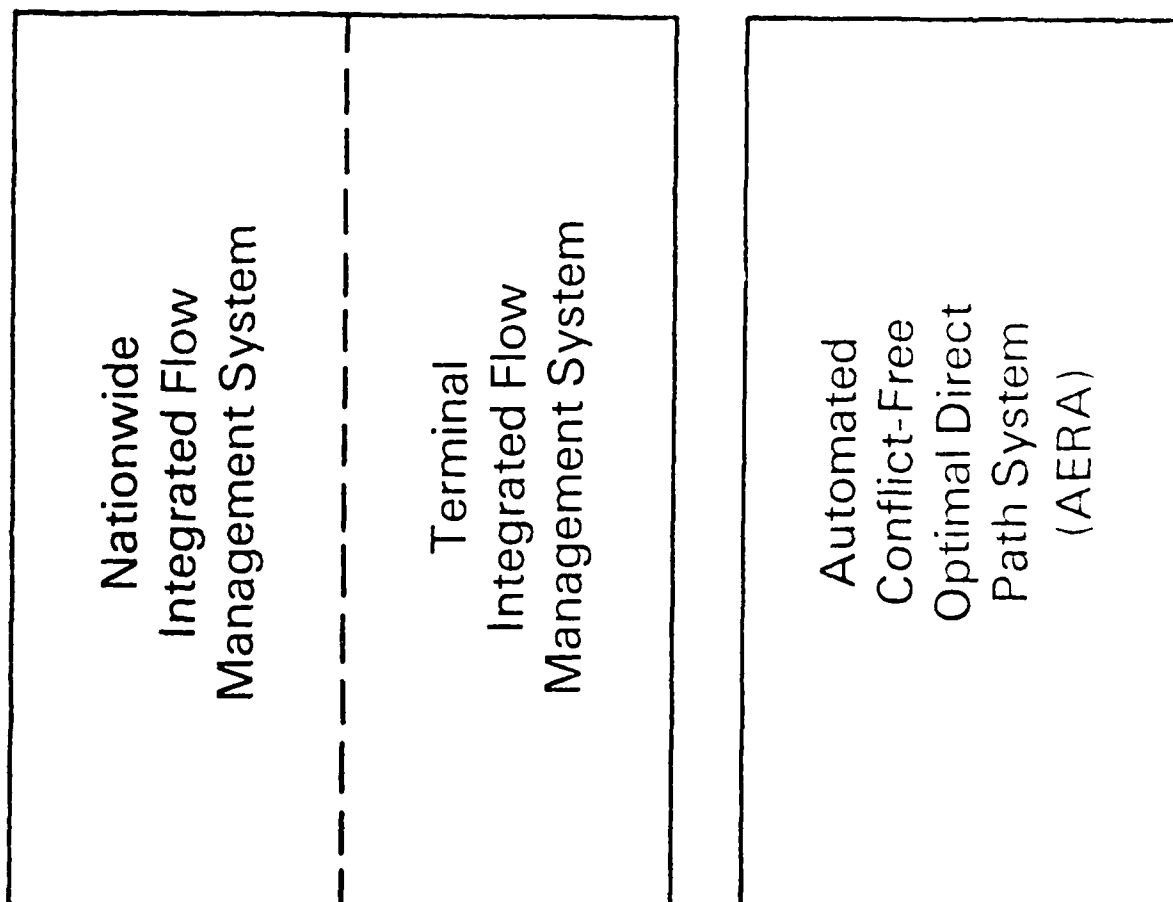
## ***ATC System Services***

Flight Plan Processing  
Radar Data Processing  
Semi-Automatic Hand-Off  
Automatic Inter-Computer Communications  
Conflict Alert  
Terminal Minimum Safe Altitude Warning  
Wind Shear Advisory Service  
Central Flow Control  
Fuel Advisory Departure Service  
Central Military Flight Reservation Service  
Airport Traffic Control Service  
Flight Services  
Essentially All-Weather Operations  
En Route Minimum Safe Altitude Warning  
Runway Configuration Management Service  
Improved Weather Service — En Route, Major Terminals and Low Activity Terminals  
Automated En Route Metering and Conflict Probe  
Automated Flight Services  
Airport Surface Surveillance and Control Service  
Conflict Resolution Advisories  
Reduced Vertical Separation Service  
Automatic Traffic Advisory and Resolution Service  
Automatic Air/Ground Communication Service  
Automatic Digital Weather Data Distribution  
National Integrated Flow Management Service  
Conflict Free Automatic Fuel Optimal Direct Routings  
Automatic Hand-Off  
Integrated Terminal Flow Management Service  
Automated Dependent Surveillance Service Over Oceans?  
Application of Alternate Separation Concepts?  
Improved Navigation Services?  
Automatic Airport Advisory Services?

## ***The Tools***

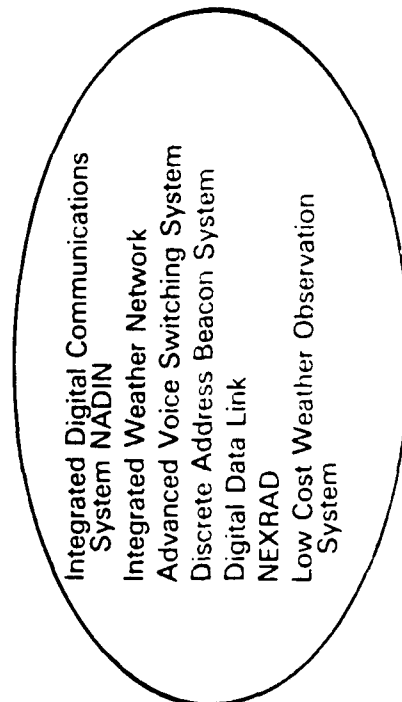
Primary Radar  
Air Traffic Control Radar Beacon System  
Surveillance Back-Up System (DARC)  
En Route and Terminal ATC Computers and Display Systems  
Paper Flight Progress Strips  
Nationwide Communications Network (Telephone and Microwave Link)  
VOR/DME/OMEGA Navigation Service  
Instrument Landing System  
VHF/UHF/HF Air-Ground Voice Communications  
Runway Configuration Management Computer  
Integrated Digital Communications System NADIN  
Active BCAS  
Microwave Landing System  
Integrated Weather Network  
Advanced Voice Switching System  
Discrete Address Beacon System  
Digital Data Link  
ATARS System  
NEXRAD  
Advanced Low-Cost Radar for Terminal Applications  
Low-Cost Weather Observation System  
Electronic Flight Information for Controllers (ETABS and TIDS)  
Computer Replacement  
Automation Support System for Terminal IFM System  
Satellites for Communication/or Surveillance?  
Future Navigation System(s)?  
Full BCAS?  
Wake Vortex Detection and Avoidance System?  
Cockpit Display of Traffic Information?

# ***Integration Concept and Systems***



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<h3>ATC System Tools</h3> <p>Primary Radar As Traffic Control Radar Beacon System Secondary Back-Up System (DARLC) Enhanced Terminal ATC Computers and Display Systems Papar Flight Programs Interpretive Communications Network (T-Intercomm and Microwave Link) VOR/DME OMNI (CA Navigation Service) Instrument Landing System VHF UHF-HF Air Ground Voice Communications</p>	<h3>ATC System Services</h3> <p>Flight Plan Processing Radio Data Processing Surv Automatic Hand Off Automatic Inter Computer Conflict Resolution Terminal Minimum Safe Altitude Warning Wind Shear Advisory Service Control Flow Control Fuel Advisory Departure Service Control Military Flight Reservation Control Military Flight Information Airport Traffic Control Service Flight Services Example: All Weather Operations En Route Minimum Safe Altitude Warning Radar Configuration Management Service Improved Weather Service En Route Radar Terminal and En Route Assignment In Route Meeting and Conflict Avoidance Airport Light Services Airport Surface Surveillance and Control Service Conflict Resolution Advisory Radar and Terminal Separation Service Radar and Terminal Separation and Recovery Service Automatic Air Ground Communication Service Automatic Digital Weather Data Distribution Automatic Transfer of Management Traffic Free Automatic Fuel Optimal En Route Routing Automatic Hand Off Integrated Terminal Flow Management Service Automated Dependent Surveillance Services One Degree Separation Conflict Improved Navigation Service Automatic Airport Advisory Service</p>	<h3>Capabilities of the ATC System at the Turn of the Century</h3> <p>Reduced Collision Risk Increased Real Time Response Increased System Reliability Improved Ground and Unaided As Communications Design Optimization for Best Human Performance Fuel Optimal Descent/Ascent Descent Eliminated Air Weather Operations Optimized Airport Throughput Maximized Runway Occupancy Time And Airport Traffic Management More Accurate Position Trend and Altitude Information Improved Separation Service Improved Separation and More Efficient and Effective Controlled Maintenance and Support of Low Altitude Operations Centralized Maintenance and Support of Low Altitude Operations Improved System Reliability and Redundancy</p>	<h3>Capabilities of the ATC System at the Turn of the Century</h3>
<h3>ATC System Tools</h3> <p>Primary Radar As Traffic Control Radar Beacon System Secondary Back-Up System (DARLC) Enhanced Terminal ATC Computers and Display Systems Papar Flight Programs Interpretive Communications Network (T-Intercomm and Microwave Link) VOR/DME OMNI (CA Navigation Service) Instrument Landing System VHF UHF-HF Air Ground Voice Communications</p>	<h3>ATC System Services</h3> <p>Flight Plan Processing Radio Data Processing Surv Automatic Hand Off Automatic Inter Computer Conflict Resolution Terminal Minimum Safe Altitude Warning Wind Shear Advisory Service Control Flow Control Fuel Advisory Departure Service Control Military Flight Reservation Control Military Flight Information Airport Traffic Control Service Flight Services Example: All Weather Operations En Route Minimum Safe Altitude Warning Radar Configuration Management Service Improved Weather Service En Route Radar Terminal and En Route Assignment In Route Meeting and Conflict Avoidance Airport Light Services Airport Surface Surveillance and Control Service Conflict Resolution Advisory Radar and Terminal Separation Service Radar and Terminal Separation and Recovery Service Automatic Air Ground Communication Service Automatic Digital Weather Data Distribution Automatic Transfer of Management Traffic Free Automatic Fuel Optimal En Route Routing Automatic Hand Off Integrated Terminal Flow Management Service Automated Dependent Surveillance Services One Degree Separation Conflict Improved Navigation Service Automatic Airport Advisory Service</p>	<h3>Capabilities of the ATC System at the Turn of the Century</h3> <p>Reduced Collision Risk Increased Real Time Response Increased System Reliability Improved Ground and Unaided As Communications Design Optimization for Best Human Performance Fuel Optimal Descent/Ascent Descent Eliminated Air Weather Operations Optimized Airport Throughput Maximized Runway Occupancy Time And Airport Traffic Management More Accurate Position Trend and Altitude Information Improved Separation Service Improved Separation and More Efficient and Effective Controlled Maintenance and Support of Low Altitude Operations Centralized Maintenance and Support of Low Altitude Operations Improved System Reliability and Redundancy</p>	<h3>Capabilities of the ATC System at the Turn of the Century</h3>
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## ***Current ATC System Services Involving Computer Data Processing***

Flight Plan Processing
Radar Data Processing
Semi-Automatic Hand-Off
Automatic Inter-Computer Communications
Conflict Alert
Terminal Minimum Safe Altitude Warning

Wind Shear Advisory Service

Central Flow Control

Fuel Advisory Departure Service

Central Military Flight Reservation Service

Airport Traffic Control Service

Flight Services

Essentially All-Weather Operations

En Route Minimum Safe Altitude Warning

Runway Configuration Management Service

Improved Weather Service — En Route, Major Terminals and Low Activity Terminals

Automated En Route Metering and Conflict Probe

Automated Flight Services

Airport Surface Surveillance and Control Service

Conflict Resolution Advisories

Reduced Vertical Separation Service

Automatic Traffic Advisory and Resolution Service

Automatic Air/Ground Communication Service

Automatic Digital Weather Data Distribution

National Integrated Flow Management Service

Conflict Free Automatic Fuel Optimal Direct Routings

Automatic Hand-Off

Integrated Terminal Flow Management Service

Automated Dependent Surveillance Service Over Oceans?

Application of Alternate Separation Concepts?

Improved Navigation Services?

Automatic Airport Advisory Services?



**ATC System Tools**

- Primary Radar
- As Traffic Control Radar Base Unit
- Secondary Radar
- Secondary's Back-Up System (DABCS)
- En Route and Terminal ATC Computers and Display Systems
- Point Flight Programs
- Navigation Communications Network
- VORTAC (VOR/DME) Management Service
- Weather Display System
- Visual Display and Ground Voice Communications

**ATC System Services**

- Flight Plan Processing
- Radio Data Processing
- Service Automation: Hand Off
- Automatic Transfer Computer
- Conflict Alert
- Terminal Minimum Safe Altitude Warning
- Wind Speed Advisory Service
- En Route Advisory Service
- En Route Advisory, Descent, and Climb Service
- Central Military Flight Reservation Service
- Advised Traffic Control Service
- Flight Service
- Emergency All Weather Operations
- En Route Minimum Safe Altitude Warning
- Altitude Configuration Management
- Improved Weather Service: En Route
- Map, Terminal and Low Activity
- Terminal
- Automated Traffic Management
- Automated Light Service
- Advised Surface Surveillance and Control Service
- Control Resolution Adjustments
- Reduced Vertical Separation Service
- Automatic Traffic Advisory and
- Automatic Air Ground Communication Service
- Automatic Digital Weather Data Distribution
- Automatic Integration from Management
- Service
- Terminal Free Automatic Fuel Journal Data Retrieval
- Accurate Fuel
- Integrated Terminal Fuel
- Management
- Service (Low Down Surveillance)
- Application of Airborne Separation Concepts
- Improved Navigation Services
- Automatic Report Airborne Services

**ATC System Capabilities**

- Reduced Collision Risk
- Improved Fuel Economy: Services and Fuel Services
- Aircraft Design Improvements
- Improved Ground Terminal and Ground Communications
- Improved Performance for Best Human
- Fuel Optimal Descent
- Fuel Optimal Ascent and Descent
- Essential: Air Weather Information
- Optimized Ascent, Descent, and Fuel
- More Accurate Positioning: Terminal and
- Altitude Information
- Improved Navigation Service
- Self-Verification: Where appropriate
- Self-Verification: Working through
- Automated ATIS (Terminal)
- Controlled Maintenance: Turnoff for
- More Efficient and Precise
- Increased Reliability
- Increased Reliability

**Nationwide Integrated Flow Management System**

**Terminal Integrated Flow Management System**

**Automated Conflict-Free Optimal Direct Path System (AERA)**

**A New, Highly Reliable, Optimum Architecture, Expandable, Flexible, and Terminal Computer and Display System**

## ***The Tools***

Primary Radar	
Air Traffic Control Radar Beacon System	
Surveillance Back-Up System (DARC)	
En Route and Terminal ATC Computers and Display Systems	
Paper Flight Progress Strips	
Nationwide Communications Network (Telephone and Microwave Link)	
VOR/DME/OMEGA Navigation Service	
Instrument Landing System	
VHF/UHF/HF Air-Ground Voice Communications	
Runway Configuration Management Computer	
Integrated Digital Communications System NADIN	
Active BCAS	Initial Operational Capability FAA Systems
Microwave Landing System	1982
Integrated Weather Network	1983
Advanced Voice Switching System	1983
Discrete Address Beacon System	1984
Digital Data Link	1984-1988
ATARS System	1985-1987
NEXRAD	1986-1987
Advanced Low-Cost Radar for Terminal Applications	1986-1987
Low-Cost Weather Observation System	1986-1987
Electronic Flight Information for Controllers (ETABS and TIDS)	1986
Computer Replacement	1986
Automation Support System for Terminal IFM System	1987-1988
Satellites for Communication/or Surveillance?	1988-1992
Future Navigation System(s)?	1992
Full BCAS?	
Wake Vortex Detection and Avoidance System?	
Cockpit Display of Traffic Information?	

THE IMPACT OF ALTERNATIVE APPROACHES IN  
AIR TRAFFIC CONTROL SYSTEM EVOLUTION

by  
Siegbert B. Poritzky  
Director, Office of Systems Engineering Management

One of the challenges in developing a scenario and roadmap to the future air traffic control system is that there are philosophical and technical alternatives which need to be examined and resolved and which can make a significant difference on the road to the system of the future. In a sense they are forks in the road, and we must have the foresight to assure they don't turn into roadblocks. Let me cite a few of them:

- o An issue long discussed is the potential for and value of changes in the balance of responsibility between the pilot and the control system in the operation of ATC. Views range widely, from concepts which would depend very heavily on aircraft self-separation based on the carriage of airborne devices to a fully strategic, fully ground-controlled air traffic control system. Terms like "distributed management" and "strategic control" are widely used, but seldom well defined. The fact is that the air traffic control system has been and remains a distributed management system in which both the control system and the aircraft crew have specific designated responsibilities. The real question is whether there are beneficial ways to change that balance of responsibility. FAA is exploring several possibilities in the program to determine the capabilities and limitations of Cockpit Displays of Traffic Information (CDTI) and in the Alternate Separation Concepts activity which was strongly recommended during the New Engineering and Development Initiatives work.

Closely tied to this area is the very old question concerning mixed airspace--the assurance of safe separation between controlled aircraft and all other aircraft, and the role of collision prevention techniques such as conflict alert, conflict resolution, and ATARS as prospective tools to improve the mixed airspace situation.

Much of the general aviation community would like to operate safely but without being fully involved in the air traffic control process. FAA is dedicated to preserve freedom of flight to the greatest extent possible consistent with safety. The direction we will head, based upon solid data, will make a difference to the evolution of the air traffic control system.

- o One of the important crossroads will be in the evolution of air traffic control surveillance. All of us see satellite surveillance in the future, but we do not yet see cost-effective ways of utilizing it. For the nearer term, the issue revolves around the future of primary radar and secondary radar combined for en route operations versus full dependence on the secondary surveillance radar system-ATCRBS transitioning to DABS. There is a significant cost impact in the

decision, as well as an impact on the computer requirement for the air traffic control system. In the computer development we are planning to provide sufficient flexibility to permit later decisions with respect to the primary/secondary radar issue, and we plan to make provisions to accommodate satellite surveillance systems when and if they become cost-effective.

- o One issue concerns the number of air traffic control centers in the future, a very old question, and much studied. In our thinking so far, we have concluded that our approach should be to utilize the existing structure of centers, but to consider placing specific functions such as, perhaps, high-altitude control and, of course, flow management functions at a few centralized locations. Again, the prospect of satellite communications has an impact, but so do safety and backup considerations, and the important social impact of major center consolidations. This is a very old issue, but one which must be kept in front of us continually.
- o The question of the navigation system of the future presents another issue. In an activity sponsored jointly by the Department of Transportation and the Department of Defense, with strong participation from FAA and help from NASA, we are examining alternatives, including prominently the Global Positioning System. The outcome of these deliberations and the decision the Nation makes with respect to navigation will have an important impact--not so much on the ATC system itself, but certainly on every user.
- o Decisions on the optimum and acceptable level of automation of the air traffic control process will have a major impact. We believe that a number of air traffic control functions can be automated. Our work on the Automated En Route Air Traffic Control System (AERA) and our successful concept demonstration of Automated Terminal Service clearly shows that the capability exists.

We have, of course, seen dramatic changes in the automation capability in modern aircraft, and the best melding of that automation with air traffic control automation represents an important challenge. We foresee increasing use of 3D and 4D area navigation systems and we expect that such centralized navigation management systems will become the standard for the future. One of the important challenges in our Integrated Flow Management concept is to achieve the best meld of aircraft/ground system automation.

Making wise choices on what to automate and in what time frame, and achieving community agreement, is a significant crossroad in system evolution.

- o The voice communication/data communication issue is old, but not yet fully resolved. FAA believes that digital communications for safety services, using the DABS data link, will offer a great many benefits. Yet progress in voice recognition systems, the desire of many pilots to communicate by voice, and the universal view that voice communications must be available for emergency purpose make this a potential crossroads issue.

- o There are major social issues that relate to the evolution of the air traffic control system. In our thinking about the future, we wish to accommodate an expanding and healthy aviation system in which the practical capability of the system is not a constraint on growth. Yet we all know that the attitude toward construction of airports, the noise and environment problem, and predominantly the funding of improvements for the National Airspace System are crucial elements in system evolution. What needs to be done to accommodate the growing system is expensive, and lack of timely decisions to invest in Engineering and Development and in implementation of new services and more efficient systems will have a dramatic effect on the real evolution of the air traffic control system--no matter how sound the planning.

AIRPORT CAPACITY INCREASES--OPPORTUNITIES,  
LIMITATIONS, AND CHOICES

by  
Siegbert B. Poritzky  
Director, Office of Systems Engineering Management

There has been a great deal of discussion of airport capacity and delay problems, many studies and analyses, and a significant amount of research and development. Today I would like to provide OTA with an update.

Before I tell you about what we are doing and what we might expect from it, I'd like to spend a few moments on the present situation, the forecast, and the financing of improvements.

One important change, of course, is the Airline Deregulation Act of 1978. While the full impact of deregulation is yet to be measured, there has already been a considerable change in the character of the industry. Patterns of service, route structures, and equipment usage are changing dramatically.

Our most recent FAA forecast indicates that while we expect air carrier revenue passenger miles to increase at a 4.8% annual rate during the 1980 to 1992 period, we expect only a 21% increase in air carrier aircraft operations over the same time period. Commuter carriers will carry 13.8 million passengers in 1980, or 4.5% of all fare paying passengers in scheduled airlines service. By 1992 these carriers are expected to carry 35 million passengers and account for 6.8% of all passenger enplanements.

By 1992, air taxi and commuter aircraft operations are expected to more than double the 1979 estimated traffic of 4.4 million operations.

Business use of general aviation is reflected in the changing character of the fleet. The more expensive and sophisticated turbine powered part of the fixed wing fleet will grow by 143% from 1979 to 1992 while the total fleet will grow by only 59%.

Change is underway within general aviation as well. The value of sales in 1980 by general aviation aircraft manufacturers in some cases is exceeding levels achieved in the first half of 1979, but the number of units sold is below the rate in 1979. The discrepancy is explained by the still increasing sales of the larger and more sophisticated aircraft in comparison to smaller aircraft.

Inflation has remained higher than expected. Fuel costs have soared and are still rising. At the Federal level, aviation must compete more directly with other modes for a share of the limited resources available to the entire transportation sector. This is important because substantial capital investments will be needed in the near future for replacement of plant and equipment. In the early development of the National Airspace System, most public and private capital investment was focused on expansion of existing capabilities and addition of new equipment. Now, however, our Federal system is facing a period that requires a far larger capital investment than the present rate of replacement of existing plant and equipment.

Airspace and airport demand are expected to increase significantly over the next decade. In order to accommodate that demand, it will be necessary to increase capital investment in the system--new and improved airport facilities, navigation and landing aids, and air traffic control facilities. Unless these capital improvements are made there is the potential that in some areas of the country the system will become saturated, and in order to maintain the current high levels of safety, it may be necessary to impose constraints on demand. We all believe that FAA's mission is to develop and maintain a safe and expanding system of airports and airways.

While the Administration's budget for airport development facilities and equipment is a growth budget, we will not be able to buy as much as we had hoped if inflation continues at the present rate. It may not be possible to expand the system as fast as we expect the demand to grow.

What does this portend for airport capacity and delay? It is perhaps useful to look at the findings of the FAA-Industry task forces at Chicago, Atlanta, Denver, La Guardia, JFK, San Francisco, Miami and Los Angeles and the lessons they've learned as we understand them.

(VU-GRAPH #1 - IFR PEAK HOUR DEMAND-CAPACITY  
COMPARISON AT FIVE AIRPORTS)

IFR demand exceeds IFR capacity today at large hub airports. The airport analyses indicate delays now reach 1 hour and more per aircraft operation during IFR peaks and that delays averaged 8 minutes per aircraft operation at those hubs in 1978.

(VU-GRAPH #2 - DELAYS AT FIVE AIRPORTS)

Even if only a modest 2% annual growth in aircraft operations is considered, the task forces believe that delays may average 25 minutes per aircraft by the year 1987. This means that even with moderate growth the problem is becoming increasingly more severe.

Considering the airport facility improvements contemplated by the task forces at the airports mentioned, they found that new runways which allow independent IFR operations would afford the biggest benefits by reducing average delays approximately 50%.

Near term improvements such as ATC procedures and more navigation aids can provide modest gains except at JFK where average delay reductions of about 30% may be possible. However, even if all the non-technology improvements were implemented--and many are controversial at the airports and even within the task forces--, delays can be expected to be 50% greater by the mid-80's than they are today.

Let me touch now on some of the things FAA is doing and the benefits that might be achieved. I have said before, especially in the "bottom line" presentation on airport capacity and delay which we presented at the New E&D Initiatives Conference in January of this year, that the amount of capacity increase and delay reduction from technology is limited.

(VU-GRAPH #3 - CURRENT MAJOR E&D PROGRAMS)

When the wake vortex problem was recognized nearly 10 years ago, two efforts were undertaken. One, by NASA, concentrated on the mechanics and causes of wake vortices, and methods to alleviate them at the source. These efforts have not reached the stage where either the airframe manufacturers or the users feel implementable wake vortex alleviation systems are achievable. The pessimists, in fact, say we are almost back to square 1 on wake vortex alleviation, even though FAA and NASA are both trying hard to make headway.

FAA, for its part, undertook the development of wake vortex detection and avoidance systems and has been moderately successful in characterizing wakes and developing meteorological means for predicting the probable location of wake vortices. A system under test at O'Hare has proven technically workable but has not been found operationally acceptable by some of the users.

It's clear that the current promise of full wake vortex detection and alleviation systems is less than NASA or FAA had hoped. While the research and development work will continue, and there is some hope for active wake vortex sensors, we must concentrate also on other approaches, because the wake vortex problem continues to be a major constraint to IFR capacity.

Automated metering and spacing has been long discussed as a potential source of at least evening out capacity at a given airport, and some enthusiasts have felt that capacity might be increased. Yet, the achievement of automated metering and spacing in implementable form



has proven elusive. We have come to appreciate the truly remarkable capability of human controllers to manage terminal air traffic and to achieve efficient airport operations--capacities which may be extremely difficult to duplicate with automation. There are, of course, things that have been done and there are more things that will be done, especially as the problem of fuel conservation becomes more critical.

(VU-GRAPH #4 - FAA PROGRAMS IN OPERATION)

Several things have been done:

- o Central flow control has been operating successfully for a number of years and is improving. It has provided an important operational element which can be fed into an integrated flow management system.
- o Fuel advisory procedures have been implemented to absorb severe delays on the ground with significant fuel savings.
- o Fuel efficient descent, a matter of great interest to airline operators who wish to fly optimal approach paths for fuel savings, has had limited success, because of the large dispersion in interarrival times resulting from the existing ATC procedures and airport dynamic variables.
- o En route metering, in a late stage of development, is another key in optimizing flow. Effective planning and coordination between centers and airports where a variety of flow metering methods are in effect help achieve smooth coordinated flow of traffic. This is a key element in the effective utilization of limited runway resources. This will also expand the use of fuel efficient descents.

Is there more to be done? We think so.

(VU-GRAPH #5 - POTENTIAL FOR REDUCED LONGITUDINAL SPACING ON FINAL APPROACH)

One study, just completed, underlines something we've long known, but have not shown explicitly, the relationship between longitudinal spacing and runway occupancy time. Reductions in IFR approach longitudinal spacing may be achievable at high-density hub airports, without higher go-around rates or increased controller or pilot workloads if a) the wake vortex problem is solved, b) the over-the-threshold delivery accuracy is improved, and c) runway occupancy times are reduced. Our study indicated that a 2.5 n. mi.

longitudinal spacing would require a typical runway occupancy time of 50 seconds. Average runway occupancy times today vary from 41 to 63 seconds, depending on airport, runway, and carrier.

- o We think the potential exists to reduce the average runway time to below 50 seconds for most current runways if there is motivation for such reductions.
- o The study also puts a damper on enthusiasm for long-range strategic control concepts with runway threshold time reservations provided far in advance of their use.

We are undertaking a project to learn more about the potential of runway occupancy time and control, but motivation, and location of gates and runway exits are important ingredients to better use of runways.

(VU-GRAPH #6 - A ROUGH ESTIMATE OF POTENTIAL SAVINGS  
FROM IMPROVEMENTS AT SPECIFIC AIRPORTS)

Let me touch on several potential improvements which promise high payoff as seen by the task forces and the FAA. These improvements have the potential to reduce the cost of delays by millions of dollars, but fall short of completely eliminating them, particularly if increased aircraft operations and changes in mix impose greater demand on airports in the future. We think that Federal expenditures for R&D to accomplish them are worthwhile, but they must be viewed only as ameliorations of the problem. Complete solutions are likely to be achieved only through major capacity increases that involve the construction of new runways. In some cases, new airports, and more intensive management of demand, including the redistribution of traffic between airports may be required to make the most efficient use of available capacity.

What are we doing about the technological possibilities? Let me review some of them.

(VU-GRAPH #7 - CURRENT EFFORTS WITH SITE SPECIFIC  
APPLICATIONS)

PROJECT: We have been working with the FAA Great Lakes Region to design a configuration management system for O'Hare to aid in the selection of best runway configuration to minimize delays. A basic system is currently being tested off-line at O'Hare. It incorporates equipment/runway outages, wind and ceiling visibility, demand and Midway airport interactions. We believe the runway configuration management system has a great deal of promise in assisting the tower controllers in keeping airport capacity at peak levels.

(VU-GRAPH #8 - INTEGRATED FLOW MANAGEMENT)PROJECT:

A program just getting underway, which we call Integrated Flow Management, may help achieve optimal trade-offs between delay, capacity and fuel efficiency at major terminal complexes in the longer term. The integrated flow management concept must integrate the functions of National flow management, en route metering, terminal flow and airport operations. This concept will use automation tools to permit the best possible integration of a variety of services and capabilities, including optimal fuel-efficient flight paths, the capabilities of 3D and 4D area navigation, adequate wake vortex protection, an optimum metering, sequencing and spacing system to ensure minimum time deviation over the threshold, the capability to provide conflict-free paths which recognize limitations of weather and shear, and runway occupancy time monitoring and control. We will be looking at how to best integrate these capabilities into the system and to establish the impact on ATC automation planning.

PROJECT:

We are actively examining the value of separate short runways for general aviation and commuters at major air carrier airports. A recent study of the top 30 air carrier airports shows the feasibility of such runways at eleven of the thirty. A detailed, site-specific study which examined two possible runway configurations at Denver has just been completed. Results indicate the concept to be feasible and of substantial benefit. We will be working with all of the FAA Regions to explore the full potential of this concept.

PROJECT:

We have developed the means to analyze the IFR approaches mentioned earlier--such as closely spaced parallels, triple parallels and converging IFR approaches. We are developing a candidate list of promising airport sites to apply this analysis method so that site-specific feasibility analyses at candidate airports can be conducted.

PROJECT:

We are evaluating the applicability of terminal airspace models which can complement the airport airfield models we have successfully developed. These models may be useful in analyzing terminal airspace capacity and delays, and especially in the development of the Integrated Flow Management concept.

- PROJECT: To aid in managing airport surface movement of traffic, FAA is testing the new ASDE-3 airport surface radar. This system will provide all-weather capability, runway and taxiway maps, with the reliability needed for higher-capacity ground and local control in low-visibility conditions.
- PROJECT: We are working on the definition for an advanced system which would include not only ASDE, but a trilateration surveillance capability. This would provide data blocks on the display for aircraft and vehicle movement and perhaps the basis for on-airport guidance and control.
- PROJECT: Potentially valuable applications of the Microwave Landing System at major airports have surfaced. We foresee innovative MLS applications, particularly precision missed-approach capability for independent and dependent IFR approaches to triple parallels, (VU-GRAPH #9-POTENTIAL MLS APPLICATION) and converging runways; and independent approaches to separate short runways for general aviation or commuters.

(VU-GRAPH #10 - POTENTIAL MLS APPLICATION)

Converging approaches are used extensively under visual approach conditions at Chicago. They are not used when the weather goes below 800/2 because the aircraft may not see each other in the event of simultaneous missed approaches. MLS guidance could allow high capacity configurations to be used in IFR operations by providing the ability to give precise navigation for missed approaches. In the case of O'Hare, they represent the difference between perhaps 170 operations per hour and 135 operations per hour.

(VU-GRAPH #11 - POTENTIAL MLS APPLICATION)

Use of separate, short runways for general aviation and commuters provide an operational solution to vortex separation problems and help cope with the growth of general aviation/commuter operations. But such runways must be located in positions where they can be operated completely independently. Full use of such runways at specific airports may require the definition of triple parallel operations, as at O'Hare, Dallas/Fort Worth or Atlanta. Resolution of airspace conflicts may be required, as for example at Kennedy where the small runway exists but is not routinely being used because of potential conflicts with other operations. The precision paths available from MLS should help. MLS may provide solutions to potential obstacle clearance, terrain or siting problems at Denver, where a study was recently completed on the feasibility of a short GA runway.

MLS may help reduce the 4300 foot parallel separation requirement for GA and commuter traffic on parallel short runways by providing additional navigation precision, high glide path angles for extra spacing, and, as above, by providing precision missed approach capability. MLS would also provide the ability to restructure approach paths at selected airports to permit segregated approaches to short runways by general aviation, helicopter and commuter operators. The use of the variable glide paths available with the MLS will permit small aircraft to follow "heavies" at a higher glide path angle as a means to ensure protection from wake turbulence.

What about the longer term programs in E&D that will improve capacity and delay? Let me mention just two of them.

(VU-GRAPH #12 - LONGER TERM E&D PROGRAMS)

The work being done in the Automated Enroute Air Traffic Control system, the AERA program, will evolve into terminal automation as well, and will become an element of the integrated flow management concept.

The FAA program to examine the capabilities and limitations of cockpit displays of traffic may show that they can be a part of the future terminal system.

Before I close, I want to say, before you tell me, that I have not talked about demand management. It is not a popular subject, although clearly redistribution of air carrier and general aviation traffic can reduce delays. Speed class and weight class segregation or flow management schemes might well produce overall savings, but means to implement such disciplines are not yet in sight. This matter is, of course, not a problem which is FAA's alone but involves the whole airport user community.

To summarize, there is much we have learned about capacity and delay. There have been disappointments, but there is far more that can and must be done to achieve optimum capability from our existing airports.

(VU-GRAPH #13 - SUMMARY OF AIRPORT  
IMPROVEMENT PROGRAMS)

Perhaps the most interesting and the most valuable airport capacity/delay improvements in the long run are direct and indirect techniques to overcome the wake vortex problems, better innovative use of runways and runway configuration, the use of separate short runways at major airports by G/A and commuters, independent and dependent IFR approaches, applications of the Microwave Landing System, and an integrated flow management concept. The prospective payoff from

technology changes and improvements seems high and seems to us to be very much worthwhile, but we must not be deluded. The technology can offer important benefits, but probably not enough to solve the anticipated problems of capacity, demand, and delay, even under modest growth assumptions. Technology and operational/economic choices must be implemented hand and hand if we are to meet the demand.

# Airport Capacity and Delay

# ***IFR Peak Hour Demand-Capacity Comparison at Five Airports (1978)***

	<u><u>Demand</u></u>	<u><u>Capacity</u></u>
ATL	137	107
DEN	116	63
JFK	88	53
LGA	77	60
SFO	72	53



# ***Delays at Five Airports***

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- Average Delays of 8 Minutes/Operation in 1978 Increasing to 25 Minutes/Operation in 1987 (With a Modest 2% Annual Traffic Growth)
- Airport Improvements Alone (Without E&D Products) Provide Only Partial Relief
  - New Air Carrier Runways Provide Largest Benefit but Potentially Feasible Only at ORD, and New Airports at ATL & DEN
  - Improvements in ATC Procedures and More Nav aids Provide Modest Gains
- Even With All These Airport Improvements, Delays Are Expected to be 50% Greater by Mid 1980's Than Today's

# CURRENT MAJOR E&D PROGRAMS

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## Wake Vortex

- NASA Efforts on Vortex Alleviation
  - Modest Success
  - Not at an Implementable Stage
- FAA Efforts on Wake Vortex System at O'Hare Not Yet Operationally Acceptable But Remains Promising.

## Metering and Spacing

- Complex and Difficult Design Task
- Not Ready for Implementation
- Important Input to Integrated Flow Management

# FAA PROGRAMS IN OPERATION

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- Central Flow Control
- Fuel Advisory Procedures
- Profile Descents
- Manual En Route Metering

# POTENTIAL FOR REDUCED LONGITUDINAL SPACING ON FINAL APPROACH

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- Recently Completed Study Indicates that 2.5 nmi IFR Standards Are Achievable If Wake Vortex Restrictions Could be Reduced or Eliminated
- 2.5 nmi Can be Achieved With Today's ATC System and an Average Runway Occupancy Time of 50 Seconds (Routinely Obtained on Many Major Air Carrier Runways)
- Further Reductions on IFR Spacings (2.0 nmi Minimum) Still a Useful Goal But Would Require
  - Solution to the Vortex Problem
  - Improved Runway Occupancy Times and
  - Better Over-the-Threshold Delivery Accuracy
  - Resolution of Operational Problems
- Implementation of Reduced IFR Standards Likely to be on Airport-by-Airport Basis

## ***A Rough Estimate of Potential Savings From Improvements at Specific Airports***

<b>Applications of</b>	<b>At These Airports</b>	<b>Potential Total Annual Savings of</b>
<b>Triple Parallels</b>	ORD	\$10 M
<b>Reduction of Parallel Runway Spacing Reqts.</b>	JFK, DEN	\$50 M
<b>Reduction of Dependent Parallel Runway Spacing Reqts.</b>	ATL, DEN, JFK	To be determined
<b>IFR Approaches to Converging Runways</b>	DEN, DFW, IAH, MIA, ORD, STL, New York	\$70 M
<b>Separate, Short GA Runway</b>	ORD, ATL, PHL, DFW, JFK, DEN, STL	\$60 M
<b>Reduction in Terminal Distances Flown</b>	ATL, DCA, OAK, JFK, ORD	\$20 M
<b>Scheduling of Runway Closures</b>	ATL, BOS, DEN, ORD, SFO New York	
<b>Configuration Management</b>	DCA, DEN, DTW, DFW, ORD, STL, SFO, New York	\$30 M
<b>Applications of MLS</b>	DFW, JFK, LGA, SFO, STL	\$80 M

NOTE: These benefits are an estimate of potential savings only and are not cumulative.

# ***Current Efforts with Site Specific Applications***

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- O'Hare Runway Configuration Management System
- O'Hare Terminal Area Flow Management System
- Use of Separate, Short Runways by GA and Commuters
- Dependent IFR Approaches
- Airspace Model Evaluation and Application
- Airport Surface Traffic Control
- Microwave Landing System Application Studies

Revisions to TERPS

Potential Applications to

- Triple Parallels
- Converging Runways
- GA/Commuter Runways
- Providing Missed Approach Capability

# INTEGRATED FLOW MANAGEMENT

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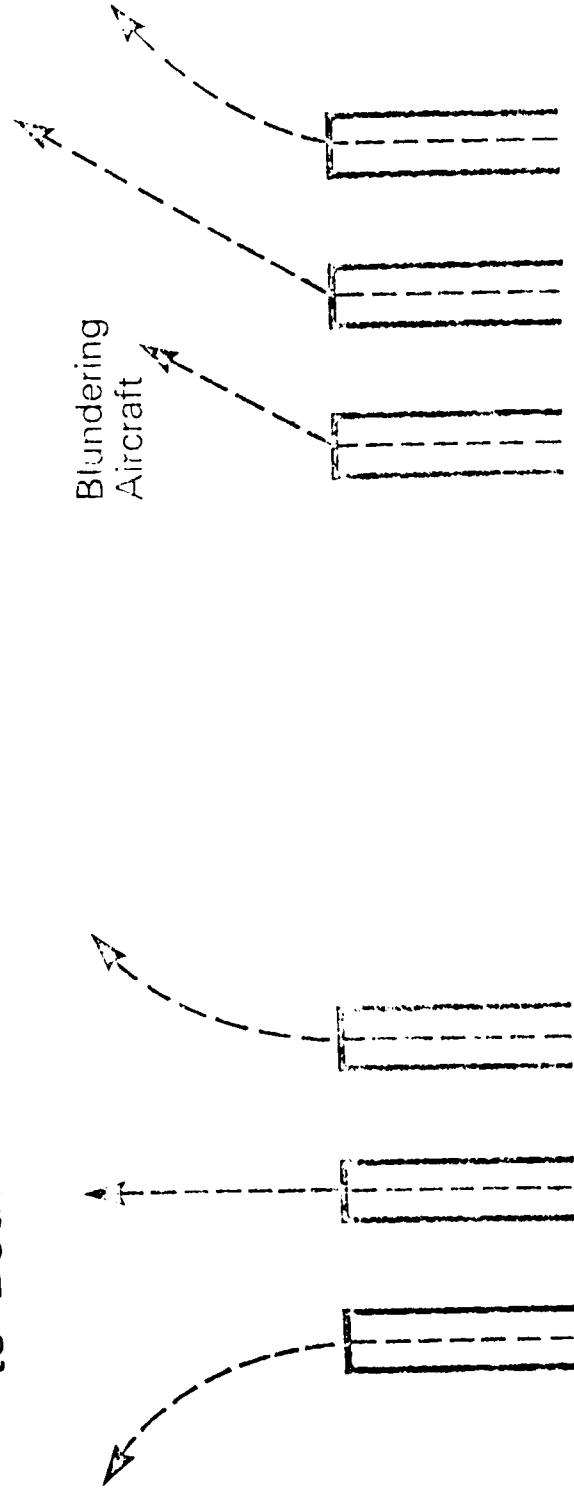
- Critical Element in Optimal Tradeoffs Between:
  - Delays
  - Capacity
  - Fuel Efficiency
- Must Integrate the Functions of:
  - National Flow Management
  - Enroute Metering
  - Terminal Flow and
  - Airport Operations
- First Step Will Address the Impact of Flight Management Systems and Advanced Avionics
- Possible Extension of O'Hare Configuration Management System and Integration with En Route Metering

# POTENTIAL MLS APPLICATION

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## Triple Parallel Arrivals

- Application of Three Parallel Arrival Runways Require:
  - Simultaneous Missed Approach Procedures
  - Protection Against Blunders
- MLS Missed Approach Guidance Provides a Solution to Both Issues



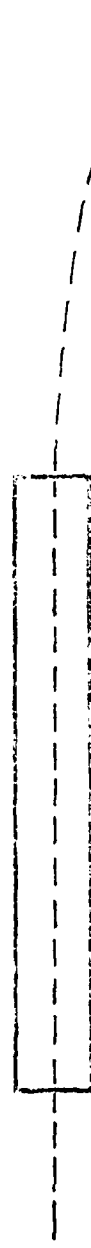


# POTENTIAL MLS APPLICATION

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## Converging IFR Approaches

- Currently Converging Approaches Used Extensively Under Visual Approaches at Chicago O'Hare
- MLS Guidance Could Allow High Capacity Configurations to be Used in IFR Operations



- Feasibility of Specific Applications and Magnitude of Capacity Benefits Depend on Specific Geometry of the Configuration

# POTENTIAL MLS APPLICATION

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## Use of Separate Short Runway

- Use of New or Existing Separate Runway for GA Provides an Operational Solution to Vortex Separations and to Growth in GA Operations
- Applications to Specific Airports May Require:
  - Triple Parallel Operations (e.g., ORD, DFW, ATL)
  - Airspace Conflict Resolution (e.g., JFK)
  - Solutions to Potential Obstacle Clearance, Uneven Terrain, or Siting Problems (e.g., DEN)
- MLS Capabilities Can Potentially Reduce the 4300' Requirement for GA/Commuter Operations on a Short Runway
  - New TERPS Would be Needed for Implementation

# LONGER TERM E&D PROGRAMS

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- Continuation of Wake Vortex R&D
  - Vortex Alleviation
  - Prediction and Tracking of Vortices
  - Knowledge of Vortices Beyond Outer Marker
- Automated En Route ATC (AERA) System
  - Major Automation Process
  - Will Feed Integrated Flow Management Program
- Cockpit Display of Traffic Information (CDTI)
  - Possible Aid to Pilot Acceptance of Automation and Reduced Spacing

# ***Summary of Airport Improvement Programs***

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- ▶ Wake Vortex Relief and Reduced Longitudinal Spacing
  - ▶ O'Hare Runway Configuration Management
  - ▶ Use of Separate Short Runways by GA and Commuter
  - ▶ IFR Approaches
    - Triple Parallels
    - Closely-Spaced Parallels
    - Converging IFR Approaches
- Reduction of Parallel Runway Spacing Requirements
- Airport Surface Traffic Control
- ▶ Microwave Landing System Applications
- ▶ Integrated Flow Management (including Metering and Spacing)
- Automated En Route ATC System Development and Extension
- Cockpit Display of Traffic Information
- Demand Management Impact Assessment

## NEAR TERM SYSTEM IMPROVEMENTS

by

Martin I. Pozesky

Deputy Director, Systems Research and Development Service

I am grateful for the opportunity to speak to you today about some of the Federal Aviation Administration's research and development activities. I will briefly describe some of our major activities, including our Airborne Separation Assurance Program, Weather Program, Flight Service Station Program, and Automation Program Evolution.

Our Airborne Separation Assurance (ASA) Program has, as its principal objective, the enhancement of the safety of air travel by reducing the potential for mid-air collisions. We are actively pursuing two interrelated systems which will fulfill this need - the Automatic Traffic Advisory and Resolution Service (ATARS) and the Beacon Collision Avoidance System (BCAS). The ASA Program elements make use of the DABS surveillance and Data Link System.

ATARS is a pilot oriented ground-based collision avoidance system. ATARS utilizes Discrete Address Beacon System (DABS) surveillance data, computed traffic and resolution advisories in a totally automated ground computer system located at the DABS sensor site and delivers these advisories to ATARS-equipped aircraft via the DABS ground-air-ground digital data link. Once the necessary equipment is installed on the ground, an aircraft must buy a new airborne DABS transponder and a collision avoidance display of his choice. This new transponder can replace his present ATC beacon transponder at a modest cost increment and will utilize the existing altitude encoder systems (which are also necessary for collision avoidance protection). It is important to note that once an aircraft has the DABS and ATARS equipment installed, he will receive immediate protection against any other aircraft which is equipped with today's ATC transponder and altitude encoder system and the new DABS transponder. This will insure that the first aircraft that equips will receive substantial protection immediately, since the transponder system is already widely implemented and is required by law for operating above 12,500 feet and many airport areas.

ATARS will operate in both terminal and en route environments within DABS coverage, providing pilots of ATARS-equipped aircraft with a comprehensive traffic advisory service and an effective resolution service. For uncontrolled aircraft, the traffic advisory service will enhance the pilots see-and-avoid capability while the resolution service will provide collision avoidance service not previously afforded by the ATC system. For controlled aircraft, ATARS will serve as a separation assurance backup to the existing ATC system. ATARS is currently under development and is expected to be implemented along with DABS.

BCAS is a collision avoidance system installed in aircraft and operates in an independent but coordinated manner with the ground air traffic control system. A "major" advantage of BCAS is that it travels with the aircraft thereby providing protection in airspace where ATARS may not be deployed. ATARS and BCAS are complementary components of the FAA's integrated program.

to provide collision protection for all airspace.

The current BCAS designs have evolved from the airborne collision avoidance system studies of the late 1960's and the BCAS feasibility demonstrations conducted over the 1972-1978 time frame.

The program is divided into two major elements, Active BCAS and Full BCAS. The Active BCAS element is a relatively simpler design appropriate for low to medium density airspace. The Full BCAS design is relatively sophisticated and incorporates a number of features not available in Active BCAS for operation in dense airspace.

Recently, Active BCAS experimental units designed and fabricated by Lincoln Laboratory of Massachusetts Institute of Technology have been delivered to the FAA for flight test and evaluation. In addition, a contract was awarded to Dalmo Victor/Textron for industry-developed prototype units. These units will be installed in air carrier aircraft for operational evaluation.

During FY 1981-82, the Lincoln Laboratory Active BCAS units will complete their engineering tests and will be extensively evaluated in operational areas on board FAA aircraft. The Dalmo Victor/Textron units will be delivered to the FAA and their evaluation in air carrier aircraft will begin. A draft National Standard for Active BCAS was just published and the development of Minimum Operation Performance Standards for certified avionics units will follow.

In its present form, the Active BCAS system cannot obtain the important directional information necessary to provide the proximity display to the pilot I spoke of earlier. This is due to the technology problems of perfecting a practical airborne antenna which can provide this type of directional information. However, recent developments in the area of airborne directional antennas hold promise of eliminating this troublesome restriction in the not-to-distant future. We are now actively investigating this possibility and, if the hoped for performance can be achieved, it may well be possible to obtain air-derived bearing information of modest quality to provide a proximity display with this Active BCAS system.

The second type of BCAS system which we are now pursuing is called the "Full BCAS." It provides a more complete service than the Active BCAS and makes use of recently developed techniques and new high speed computer technology. When operating in radar coverage, this system will provide directional information of higher quality than is possible even with the airborne directional antenna I spoke of earlier. Because of this important feature, this system can also provide an electronic display of surrounding aircraft in addition to both horizontal and vertical maneuver commands in all environments.

Full BCAS units will be developed by industry under a contract about to be awarded. Following design definition, engineering models will be fabricated for flight test and evaluation by the FAA. This activity may be followed by the fabrication of prototype units for operation in air carrier aircraft.

## AVIATION WEATHER

The overall objective of the Aviation Weather Program is to provide timely weather information to all users of the Nation Airspace System, to significantly improve the capability for detection of hazardous weather phenomena, and to provide rapid access to the national aviation weather data base by all users.

The Weather Program is separated into three development areas. The first area is directed to developing capabilities for processing, distributing, and display of weather data to all users in the National Airspace System, the FAA or the public. Plans in this first area involve the use of the Flight Service Station computers now under procurement that provide automation support to the present Center Weather Service Unit meteorologists in the en route centers. To display tabular weather data to the controllers, the Electronic Tabular Display Subsystem (ETABS) and the Terminal Information Display System (TIDS) will be used. Our National Airspace Digital Interchange Network (NADIN) will be utilized for inter and intra facility weather data communication.

The second area, Weather Radar, involves the development of a new generation of weather radar using doppler technology to provide radial wind velocity and velocity spectrum width in addition to reflectivity data, detection of hazardous weather phenomena is to be greatly improved through the application of doppler radar technology. A joint program was established in 1979 between the Departments of Commerce, Defense, and Transportation, with a Joint System Program Office (JSPO) established within the Department of Commerce to develop and implement the Next Generation Radar (NEXRAD). The FAA is providing both manpower and funding resources to the NEXRAD JSPO and expects this new radar system will satisfy its requirements for weather radar for the detection of hazardous weather in the en route environment. It should be noted however, that due to siting requirements, scan rates and display update rates, the detection and display of hazardous weather phenomena in major terminals may require a separate terminal weather radar.

The NEXRAD program is following the A-109 major system acquisition process, with multiple system definition phase contracts scheduled for award in the fourth quarter of FY-81 and multiple validation phase contracts scheduled for award in the fourth quarter of FY-82. Full scale development will be initiated in FY-85 with a production release in late FY-86.

The third area, Automated Weather Observations Systems involves the development of new weather sensors and the capability to process sensor outputs into a complete weather observation for voice and digital transmission. The FAA is completing the development of two systems for processing and generating observations. The first is a simple system identified as "WAVE" (Wind and Altimeter Voice Equipment) for providing a wind and altimeter setting observation with a voice output for use at airports with an instrument approach procedure requiring local altimeter settings; and an Automated Low Cost Weather Observation System (ALWOS); to provide a basic observation capability at general aviation airports.

A fully automatic weather observation equivalent to a human observation requires the development of several new key sensors in which work has been initiated jointly with the National Weather Service and the Air Force.

A joint development and implementation program between the Departments of Commerce, Defense, and Transportation for procurement of the Automated Weather Observation Systems is expected to begin in 1981. Joint operational requirements and functional specifications are scheduled for approval in FY-81 and contract awards for development and production of semi-automated weather observation systems and development of key sensors are planned in FY-82.

Semi-automated systems would be available for field deployment in 1984. Key sensor development would be completed in 1984 and production sensors would be available for upgrading the semi-automated systems to fully automated systems in 1986.

#### FLIGHT SERVICE STATIONS

The existing Flight Service Station System is comprised of 313 stations. Flight services are provided in a highly labor-intensive manner, with most services being provided on a person-to-person basis. The projected growth of general aviation and the resulting demand for services will require more than a doubling of system capacity by 1995. To meet this demand by expanding the existing "manual" system would require the hiring of 6500 additional flight service specialists with an attendant annual system operating cost of \$320 million per year. The modernization and automation of the Flight Service System as planned will meet the 1995 demand with the current staff of 5000 specialists or possible even less with an annual operating cost of \$140 million/year. The cumulative cost savings to 1995 due to automation of the system would be \$1.5 billion. Key to this concept is pilot self briefing to be discussed a bit later.

The Flight Service Automation System contract award was made June 17, 1980 to three contractors, each for a one-year design verification contract. During this period the contractors will verify their software and computer system designs. One of the three contractors will be selected for the production contract, to produce and implement FSS automation to two steps, model 1 and model 2.

Model 1, limited automation, is to be deployed to 41 level III FSSs beginning within one year after contract award. It provides at the specialist's position retrieval and display of weather and aeronautical data and flight plan entry and processing.

Model 2, full automation, is to be deployed to 61 FSSs to be located at airports which are major centers of general aviation activity. At the specialist position, in addition to the model 1 capabilities, will be weather radar and weather graphics and additional aeronautical information and processing.

The model 2 system has the capacity to handle the long-term flight service demand whether from the specialist or directly from the pilot. 11



also provides software and interface to support direct user access to the system.

The research and development program in Flight Service Stations is primarily the development of model 3 or pilot self briefing. Model 3 has three major subdivisions:

- (1) User self-briefing via computer terminals called Direct user Access Terminals (DUATS). An initial complement of DUATS is included in the current systems acquisition to implement the operational capability to encourage users to purchase DUATS for self-briefing and flight plan filing.
- (2) Direct user access via push button telephone. This mode of direct access requires application of Voice Response System (VRS) technology and of the capability to automatically process weather aeronautical, and flight plan data.

Currently, the automatic processing of data and conversion to voice for response to direct user access via push button telephone entry provides surface observations, terminal forecasts, winds aloft, and warnings of severe weather for any of over 700 weather reporting points in the country. This initial capability is currently undergoing public demonstration in the Washington, D.C., area and the Columbus, Ohio Flight Service Station area.

As new and/or expanded capabilities are developed, they will be subjected to test and evaluation. Following operational demonstrations they will be scheduled into the sequential updating of the operational FSS automation program.

- (3) Direct user access via any type telephone. This mode of direct access requires application of Voice Recognition (VR) technology. The FSS system responds to this input using the previously developed voice response system. The voice recognition mode of access is currently under test and evaluation.

#### AUTOMATION - EN ROUTE AND TERMINAL

The En Route program includes numerous activities aimed at upgrading the system, however, I'll only address a few of them here.

Since the inception of the air traffic control system, the method of posting flight data information to the air traffic controller has been the paper flight strip. Before the introduction of the present NA Stage 4 ATIS system, flight data information was entered and updated manually by pencil on the flight strip. The present system uses electro-mechanical flight strip printers which, under computer control, print initial and updated flight data on paper strips and distribute the strips to the proper sectors. This system requires mounting or "stuffing" of the strip by hand in the flight strip holders, placing the holders in the desired position in the flight strip bay, updating the flight data by pencil, and entering update information into the computer by means of a manually operated keyboard.

device. This is a cumbersome operation which consumes much of "D" controller's and "A" controller's time.

The Electronic Tabular Display Subsystem (ETABS) effort is involved with the application of electronic display technology in the replacement of the flight strip printers and paper flight progress strips now in use at all Air Route Traffic Control Centers (ARTCCs). Through the use of electronic displays, processors, and touch entry devices, ETABS will automatically provide non-radar flight and control data to the data ("D") controller at each en route control sector.

At the current air traffic level, approximately 8,000 controllers are required to staff the existing sectors in the Air Route Traffic Control Centers. A Recent study indicates that with the forecasted growth in air traffic the controller staff will need to be increased significantly with the creation of new sectors which will be necessary to meet future traffic demands. The study shows that the implementation of ETABS will result in an increase in controller productivity with a consequent reduction in sector staffing growth rates. Based upon an ETABS implementation in the 1986-1987 period, present value cost savings through 1999 are estimated to be in excess of \$400 million.

ETABS consists of the computers, displays, and message entry resources necessary to support the en route sector positions. A distributed processing network concept is used to accept, process, and distribute flight planning data to recipient sector positions and to accept, process and transmit controller originated messages to the NAS en route Central Computer Complex (CCC).

The en route metering function organizes airport arrival traffic in the en route airspace by metering flights to their destination airports. Metered flights are scheduled for delivery to a merge point with a uniform time separation to match the acceptance rate specified for the merge point or vertex. The automated metering process extends beyond the individual center's boundary via existing computer-to-computer interfaces by the exchange of metering-related data.

The metering function determines a tentative landing time for an aircraft. A list of these landing times will be displayed for all aircraft arriving at a given metered airport.

In order for the metered flights to meet their landing time, delay absorption strategies are generated to absorb any required delay. Flights are monitored at various times along their routes to determine current absorbable delay and the appropriate delay absorption strategy, such as outer fix, speed reduction, descent or primary hold. These advisories are displayed on the plan view display of the R-controller who either has control of the flight or controls the sector containing the related fix.

The Conflict Resolution Advisories function is designed to provide the en route radar controller with a display of possible alternatives for the resolution of conflicts identified by the conflict alert function. The prime objective of the conflict resolution function is to reduce instances

of system error, the violation of en route separation standards, by reducing decision-making time in complex encounter situations. By display of possible alternatives for the resolution of conflicts, the prospect is that the conflict resolution function will offer confirmation to the resolution preferred by the controller, who generally can introduce to the situation other considerations beyond the capabilities of the current levels of automation, such as weather, communications failures or the presence of uncontrolled VFR aircraft.

The objectives of our Terminal Automation Program are to provide improvements to the existing terminal automation systems and the development of new system capabilities which will result in increased safety, improved controller productivity, and reduced fuel consumption of traffic in the terminal control areas.

System improvements for which the development programs have recently been completed include: The field evaluation of an expanded ARTS III system at Tampa-Sarasota which provides the capability to process digitized data from a remote radar site and display it on local radar control consoles and remote tower cab digital displays; development and operational evaluation at the FAA technical center of a new Airport Surface Detection Radar (ASDE-3); field evaluation at a medium activity airport of an electro-mechanical system for visual confirmation of voice take-off clearances; and hardware/software changes to ARTS III to enable it to operate with DABS.

Development projects currently being initiated include the expansion of ARTS II processing capacity and the addition of beacon tracking, conflict alert, and minimum safe altitude warning to this system; development of TAGS, a capability for interrogation of transponder-equipped aircraft on the airport surface, and development of terminal sequencing and spacing.

A word about terminal sequencing and spacing may be in order. Terminal Sequencing and Spacing is a development program designed to take the first major step towards automation of a complex air traffic control function: That of sequencing, scheduling, and spacing terminal arrival aircraft.

In general, the sequencing and spacing will control the flow of arrival aircraft into the terminal area, from the en route feeder fixes to the runway. It determines the final landing order based on each aircraft's nominal landing time, using predefined flight paths, and establish schedule times at various points for each aircraft which will assure proper spacing of aircraft at and inside the final approach course intercept. The sequencing and spacing aids in the control of arrival aircraft by the generation of recommended commands to satisfy the established schedules.

An increase in system capacity may be achieved by providing more consistent inter-arrival spacing of aircraft, thus assuring an increase in runway utilization. The automated sequencing and spacing function may also prove beneficial in other areas of productivity, that is, an overall reduction in arrival delays and the absorption of any necessary delays in the most efficient manner available.

Safety will be maintained by assuring that recommended control actions are within the bounds of aircraft performance characteristics, and by assuring that control is in accordance with existing ATC procedures and practices.

## LONG TERM ATC SYSTEM IMPROVEMENTS

by  
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of Systems Engineering Management

### INTRODUCTION

You have heard from previous speakers about many of the activities underway and received a broad perspective of the improvements planned for the ATC system. This presentation will deal with some of our long term system improvements.

The programs I will address are the Integrated Flow Management Program aimed at developing a concept to integrate National, en route, terminal and airport flow management operations such that delays and fuel consumption will be minimized by making best use of airport and airspace resources.

I will talk about our work to automate the en route portion of the ATC system, and our efforts to identify new and alternative methods to provide safe separation. I will discuss briefly our major effort to replace our current computer system with one capable of satisfying the future demands of increased aircraft operations and higher levels of automation will also be described. Finally I will discuss our work in human factors.

### INTEGRATED FLOW MANAGEMENT

Integrated Flow Management is a requirements definition, concept development, and integration activity. The integrated flow management concept must integrate the functions of National flow management, en route metering, terminal flow and airport operations. This concept will use automation tools to permit the best possible integration of a variety of services and capabilities, including optimal fuel-efficient flight paths, the capabilities of 3D and 2D area navigation, adequate wake vortex protection, an optimum metering, sequencing and spacing system to ensure minimum time deviation over the threshold, the capability to provide conflict-free paths which recognize limitations of weather and wind shear, and runway occupancy time monitoring and control. We will be looking at how to best integrate these capabilities into the system and to establish the impact on ATC automation planning.

The Integrated Flow Management Program addresses two time frames. One phase covers the longer term, addressing the total flow management concept around the turn of the century. To provide a shorter term focus for the flow management program it also addresses the near term period of approximately the next five to ten years and is predicated

upon the assumption that even with time and equipment constraints, improvements can still be made. For example, we have been working with the FAA Great Lakes Region to design a configuration management system for O'Hare to aid in the selection of best runway configurations to minimize delays. A basic system is currently being tested off-line at O'Hare. It incorporates equipment/runway outages, wind and ceiling visibility, demand and Midway airport interactions. We believe the runway configuration management system has a great deal of promise in assisting the tower controllers in keeping airport capacity at peak levels. We will be delivering a runway configuration management system for realtime operational tests at O'Hare at the end of this fiscal year. We are examining the applicability of this type of aid to other airports and envision this as a potential element of the flow management concept.

A preliminary concept of Terminal Flow Management has been postulated and is being examined with respect to its ability to accommodate:

- . 4D RNAV
- . Flight Management Computers
- . Severe Weather
- . Wind Shear and Wake Vortex
- . Metering and Spacing
- . Departures
- . Multiple Runways
- . MLS Procedures
- . Profile Descents

and to interface with en route metering.

Concepts for National Flow Management are also being investigated. These concepts are viewed as enhancements of our current Central Flow Control Facility. It is envisioned that this enhanced capability will be better able to balance the demand on and the capacity of the system since it will have better and more timely information and will be capable of directly interacting with all center and terminal facilities.

The en route element of the flow management concept is contained within AERA and we will be addressing that program in detail momentarily.

These elements of flow management--airport, terminal, en route and national--will be combined and integrated and will form the integrated flow management concept.

#### AUTOMATED EN ROUTE ATC (AERA)

The objective of this program is to develop the concept, functional

description, and engineering requirement for an advanced ATC system which will automatically perform most en route planning and control processes under the active management of controllers. This system will provide better accommodation of flexible, fuel efficient profiles, increase ATC productivity, reduce historic causes of system errors, increase ATC service availability, and reduce the potential for pilot error.

AERA will be a fully automated system, embedded within each en route facility, that will (a) automatically plan conflict-free, fuel efficient profiles for aircraft operating in positively controlled airspace, (b) generate ATC messages needed to execute the planned profile and assure aircraft separation, and (c) deliver ATC messages via a data link or VHF voice channel. AERA will protect against system failure by providing a coast capability and backup clearances and will be compatible with the backup systems such as DABS/ATARS and BCAS.

The AERA operational concept assumes that ground-based computers will automatically perform most of the routine ATC planning and control functions under the active management of air traffic control specialists. For IFR en route aircraft these functions will automatically produce a plan of clearances to be issued, either automatically or manually, at appropriate times. The clearance plan, if followed, will ensure that all controlled flights will remain conflict-free, fuel-efficient, and when appropriate, metered.

Aircraft carrying an FAA-accessible data link, area navigation equipment, and a flight management computer will be able to take full advantage of the capability of the AERA system. Pilots flying aircraft with the full complement of equipment will be able to file for and, in most cases, receive precise, direct route, fuel optimal flight profiles.

In AERA, the volume of airspace within which the computer can control flight movements by issuing clearances to pilots is known as its "control region." To avoid discontinuities in the planning and control process, each AERA system begins its planning process before an aircraft enters the control region. It is planned that AERA control sectors will be staffed by two controllers and that the airspace controlled would be several times the size of current day NAS sectors.

The productivity increases sought in AERA imply an increased traffic load for each controller, certainly a heavier load than an unaided controller can handle, so the impact of a system failure on smooth traffic flow and on safety will be much more severe than in the current system. Thus, reliability of both hardware and software will be critical; backup procedures will be more complex; and human factors considerations pertaining to these backup procedures will be more important.

The basic philosophy for AERA system integrity is to design the AERA hardware and software so that faults of hardware, software, and algorithms have no effect on the performance of the automated system. Availability of this fault tolerant computing system at an en route center must be as high as state-of-the-art technology will permit--close to 100%. Our evaluation of computer technology of the 1980's indicates that a fault tolerant system in which a failure will occur only under the most unusual circumstances can be built at a reasonable cost by the end of the decade. This subject will be discussed further in the Advanced Computer Program.

We have currently formulated a detailed AERA system operational concept and are in the process of developing a detailed functional description to be included as part of the Computer Replacement Program. In addition, a real-time AERA test bed capable of examining the role of the controller in an automated environment, as well as demonstrating concept feasibility, is being developed. A first demonstration of AERA's ability to accommodate fuel efficient flight is scheduled for December of this year.

#### ALTERNATIVE SEPARATION CONCEPTS

Up until now, we have been discussing a rather sophisticated Air Traffic Control system dealing with well-equipped aircraft operating in a controlled environment. Let us now discuss the other end of the spectrum, namely, aircraft operating in the system with little or no interaction with the ATC system. The Alternative Separation Concepts program is investigating the feasibility of permitting properly certified pilots to conduct flights in Instrument Meteorological Conditions (IMC) on a relatively unconstrained, autonomous basis.

There has existed for some time the belief that in certain airspace under specific conditions, as yet undefined, that flight could be conducted in Instrument Meteorological Conditions (IMC) with the freedom approaching that experienced under VFR. One such concept, conceived during the New E&D Initiatives effort and termed Electronic Flight Rules (EFR), has been examined in some detail by Lincoln Laboratory.

This concept relied on DABS coverage and the use of a collision avoidance system such as BCAS or ATARS. The results of the Lincoln Laboratory effort indicate such an approach is technically feasible and identifies the functional requirements that a "black box" would have to be provided to permit EFR flight in an en route environment. However, this study did not address the problem of terminal airspace nor did it consider procedural changes or airspace modifications which might lead to a different set of functional requirements. Obviously, alternative separation concepts are not limited to the EFR concepts, and further effort is required. As a first step toward continued examination of this issue, we will be conducting an ASC Workshop at



the FAA Technical Center early next year and will involve all interested elements of the aviation community. It is hoped that a number of promising alternatives will be identified during the course of the workshop and that the most promising alternative will be identified and plans for development and feasibility demonstration can then be formulated.

#### ADVANCED COMPUTER PROGRAM

You have just seen a sampling of some of the long term FAA programs which are designed to accommodate the continuing growth in air traffic and the need to achieve higher levels of safety, performance and efficiency in the operation of the Air Traffic Control system. This need, coupled with the lack of expansion capability of the current ATC computer complex, is the basis for the requirement for a significant upgrading of the ATC computer system by the end of this decade. The Advanced Computer Program is designed to satisfy this requirement and to lay the foundation for the automation system which will carry us to the turn of the century, and even beyond.

The new en route computer system will be designed to provide the cornerstone for substantial air traffic control evolution in the post 1990 era. The new computer system will:

- o Provide increased automation of the planning and control functions currently performed by the air traffic control specialist. These "automated" decisionmaking functions will be closely tied to an integrated flow management system that will tie together the en route and terminal functions and the national flow control capability. All these functions will make extensive use of the discrete address beacon system data link.
- o Utilize improved weather data based on the introduction of doppler weather radars in its automated planning functions.
- o Accommodate satellites for surveillance and communication, should they become economically viable options in the future.
- o Permit the use of cockpit display of traffic information to allow the pilot to assume additional responsibility in the cockpit should this prove feasible.
- o Include the consolidation of terminal radar control into the en route facilities should that be determined desirable.
- o Provide the capability to upgrade the terminal computer system using hardware and software modules developed for the en route application.

We wish to have the option of performing en route and terminal

functions in integrated facilities or in separate facilities utilizing common equipment and data sources. In addition, this program will satisfy the need for support facilities utilized for development, certification, and training.

The architecture of the replacement system will be such as to ensure a functional reliability/availability approaching 100%. It will be capable of being integrated into the existing air traffic control system in a way which is initially transparent to controllers, pilots, and other users. It will possess sufficient flexibility to permit the air traffic control process to change to one in which the major portion of the control functions are performed automatically by computers. It will accommodate changes in computer technology during a long system life in such a way that no wholesale system replacement will be required in the future. It will accommodate anticipated aviation growth and changes in the mix of aircraft using the air traffic control system. Finally, the replacement system must be able to integrate new air traffic control processes and new air traffic control data sources that may arise from the evolution of supporting navigation, communication, surveillance and weather detection and forecasting systems.

The acquisition of the air traffic control computer replacement system is being carried out as a major system acquisition as defined by DOT Order 4200.14A, which is the DOT order implementing the guidance provided in OMB Circular A-109. In accordance with that order, the program is structured as a four phase program with decision points and associated TSARC's occurring at the start of each phase.

Competition is maintained throughout the initial phases of the program. The decision on whether to maintain two contractors through the relatively expensive full-scale development, test and evaluation phase will be made on the basis of a cost vs. risk analysis at the conclusion of the design and critical subsystem demonstration phase. Present planning, however, is being done on the assumption that two contractors will be carried through the third phase. This approach assures minimum risk in achieving the desired system on the desired schedule.

The initial phase of the program will involve a variety of procurements, including technical support efforts and studies. These activities may be categorized as: requirements study; long-term requirements analysis and supporting technology studies; management; specification development for design concepts; and solicitation and evaluation of alternative computer system design concepts.

A brief status report follows:

The requirements study team has completed a draft of the system requirements statement and that document is entering the coordination

process with a release of the final document scheduled for January 1, 1981.

Technology tasks supporting the preparation of the specification and design evaluation criteria have been underway for some time and certain key tasks have been completed.

The specification and evaluation criteria definition work was started in March 1980. A draft specification is planned for early 1981.

The complete procurement package is scheduled to be ready to go out to prospective bidders in December 1981 with contract award planned for June 1982.

Preliminary funding estimates have been developed based on past experience with similar programs, discussions with industry, and our initial assessment of the impact of A-109 on the development and implementation process.

These estimates indicate the cost for replacing the air traffic control computer mainframes and software plus replacement of the displays is approximately \$2.8 billion dollars including inflation.

#### HUMAN FACTORS

So far we have been discussing control systems, automation concepts, scenarios, advanced technology, and computers and their application to the air traffic control systems of the future. But we have said little or nothing about the other, and, perhaps the key element in the present and the future system, the human being. Human limitations constitute the major cause of accidents today. Systems of the future must be based on proper allocation of functions between man and machine. We have an extensive human factors program aimed at system performance enhancement and error reduction, both in the cockpit and on the ground.

First let us discuss the controller issue.

#### Controller Performance Enhancement and Error Reduction

Though controller related accidents have been rare, we have experienced an increased number of system errors in recent years. An analysis of these errors showed that over ninety percent of them involved some element of human error such as inattention to duty, poor judgement, lack of coordination among controllers, failure to properly identify aircraft, and poor communication skills. These findings have resulted in the establishment of controller performance improvement projects aimed at the elimination of error causes in the present system.

The introduction of advanced data technology into the ATC system has brought the potential of new sources of system error in terms of controller interaction with automation. Such issues as boredom and inappropriate intervention into automatic controls and inability to detect and intervene in automation failure situations have lead to the establishment of projects aimed at defining appropriate controller roles, compatible with increasing automation. These projects in the aggregate are called the Controller Performance Enhancement and Error Reduction, or CPEER program. The goals of the program are to improve controller performance and reduce error potential in the present and evolving system to improve system safety and efficiency.

#### The Present ATC System

In the present ATC system, the problems being investigated are:

- o Improved information display that will assist the controller in heavy traffic situations.
- o Optimally designed sector suite to accommodate planned near term additions and training.
- o Formulation and implementation of standard operating practices to help reduce system errors.

With respect to the evolving ATC system, we have a number of concerns such as:

- o How do we assure controller confidence that automated system elements are in fact doing the proper job?
- o How do we assure that with increasing automation system induced errors and blunders are reduced?
- o How do we enhance controller performance in automation failure situations and maintain vigilance during routine automation controlled operations?
- o How do we assure acceptance of the system by pilots, controllers and users as it evolves through increasing levels of automation?

In this area, specific problems being addressed are:

- o The role of the controller in an automated ATC environment.
- o The ability of the controller to perform his assigned job in an automated ATC environment.

- o The optimal design of the interface between the controller and the computer in an automated ATC environment.
- o The feasibility of the concept of "auto-controller" analogous to "auto-pilot."
- o The impact of passive and active CDTI on the controller.

To successfully solve these defined problems, basic tools are required, and this represents the third area of the CPEER effort. In this area entitled "Methodology and Facility Support" we have included tasks such as:

- o Development and validation of controller performance and workload measures.
- o Development and validation of objective and reliable ATC system effectiveness measures.
- o Expansion of the current ATC simulation facility to emulate system configurations planned for the future.
- o Develop the capability to provide full mission simulation from the controller point of view.

Let us now turn to the pilot side of our human factors program called APEER - Aircrew Performance Enhancement and Error Reduction.

Historically, pilot error is involved as a factor in approximately 60% of air carrier and 88% of general aviation fatal accidents. Recent data from the NASA Aviation Safety Reporting System indicates that pilot error is also a significant factor in aviation incidents. Further, as aircraft powerplants, airframes, and systems improve, and as aircraft flight envelopes open to higher performance capabilities and lower minimums, the occurrence and consequences of pilot error are expected to increase in proportion to other factors. In 1975, a special task force formed by the DOT to study the FAA safety mission recommended that the "FAA undertake a major safety research program to assure that future systems are designed around reasonable criteria for human error." Concurrently, the FAA Office of Systems Engineering Management had undertaken an in-house study to identify the human factors problems associated with both air carrier and general aviation accidents and incidents. The results of this study were briefed to industry and government groups and the feedback used to formulate a program of human factors research to supplement a number of ongoing FAA projects specifically aimed at reducing pilot error by identifying needed but unsupported human factors activities. In 1978, these ongoing and new projects were pulled together under a central focal point and entitled the Aircrew Performance Enhancement and Error Reduction, or APEER, program.

### General Aviation Programs

In the general aviation problem category, we have identified and are working on the following:

Problem: The high number of weather related accidents occurring between the basic private and instrument phase of general aviation pilot licensing.

Problem: Excessive pilot workload and inappropriate judgement are suspected to be prime causes of pilot error in general aviation accidents. The extreme diversity of existing and planned general aviation cockpit equipment as well as the wide variation of pilot experience and judgement capability will cause pilot error problems to persist.

Problem: There are no readily available general aviation human factors laboratories in which data can be collected regarding general aviation cockpit operation in current or advanced avionic equipment or ATC system scenarios.

We are also categorizing general aviation accident data to determine additional human factor problem areas. The leading problems relating to workload or man-machine interface design will then be rank ordered, analyzed and potential solution areas identified.

### Air Carrier Programs

In the Air Carrier category we are examining the following problem areas:

Problem: Not enough is known about the potential benefits or liabilities of head-up displays in contributing to more flexible and safer operations in air carrier aircraft during approach and landing.

Problem: The current generation of air transport aircraft has a very complicated alert and warning system which could contribute to pilot judgement error and may not indicate the correct priority of action immediately.

Problem: The introduction of advanced cockpit concepts and advanced ATC system improvements during the remainder of this century will impose as yet undefined requirements on cockpit information processing and displays.

Problem: The current status of cockpit standardization is unknown. The problems of non-standardization, vis a vis regulation, have not recently been assessed.

### General Programs

The final category of the APEER program deals with general areas common to both GA and Air Carrier. In this category we are dealing with the following:

Problem: Uncertainty exists as to whether mandatory altitude callouts by controllers during Airport Surveillance Radar approaches would reduce landing accidents.

Problem: No fully acceptable, scientifically validated or widely accepted, systems approach to measuring pilot workload and performance exists that will measure the utility of various cockpit configurations.

Problem: A number of accidents and incidents have been caused by aircraft taxiing onto active runways during takeoff, landing, or taxiing operations. FAA and NASA records indicate that 279 cases of this type have been reported over the past 10 years.

Problem: The rising cost of fuel has placed increased emphasis on more efficient use of airspace. World-wide practices for the determination of separation standards have been under discussion in ICAO. Although not yet fully quantified, it is evident that human error in navigation is a significant contributor to the failure of the aircraft to adhere to designated route centerlines.

Problem: Now that the ability to provide traffic information to the cockpit exists, it is unclear what the pilots' ability is to use this information or what the impact of his using it is on the ATC system. The benefits and liabilities of various types of traffic information are unknown.

This last problem of the APEER program is the genesis for our program in Cockpit Display of Traffic Information (CDTI) which I will now discuss.

### Cockpit Display of Traffic Information

This is a joint NASA-FAA program with the NASA Ames Research Center responsible for basic human factors display and workload efforts, and the NASA Langley Research Center responsible for air carrier cockpit simulation. The Federal Aviation Administration Technical Center is responsible for general aviation cockpit simulation using a low-cost weather radar presentation, and ATC system simulation and integration with the cockpit.

We are conducting this program in three phases which are aimed at evaluating the most practical potential CDTI applications as early as possible. The three phases of the program are the Concept Development Phase (Phase I), the Concept Validation Phase (Phase II), and the

Extended Applications Phase (Phase III). In early Phase I, which concentrates on the evaluation of a passive implementation, the pilot will employ CDTI in the role of monitoring appropriate surrounding traffic and assist with the non-passive tasks of merging and spacing. Phase II will validate the results developed in Phase I in an operationally complete environment. The early potential applications from Phase I and II include:

- o Controller assistance to the pilot in merging and spacing.
- o Improved situational awareness.
- o ATC back-up assistance in case of equipment failures.
- o Blunder detection.
- o Airport capacity improvements in a high-density terminal area with a traffic mix of diverse performance classes (Denver TCA).
- o Integration of CDTI and CAS functions through a shared display.

The latter part of Phase I and III will address extended applications of CDTI to additional aircraft classes and operational tasks including more active pilot use of the displayed information. Some Phase I and III potential applications include:

- o CDTI as a separation aid (not CAS) in low-density airspace.
- o Traffic awareness in a traffic mix of diverse performance classes (other terminal airspace than the Denver TCA).
- o A self-merging aid.
- o Advanced active functions (weather avoidance, 4D RNAV, runway occupancy, and other practical ATC tasks).

Although this program is designed to limit its scope to the CDTI concept, there will be interactions between this program and other FAA and NASA programs. For example, the CDTI program will investigate the potential interactions between a CDTI and cockpit Collision Avoidance System displays, both as separate and integrated devices. Flight testing will be accomplished using an experimental DABS data link as a convenient pipeline to the experimental CDTI aircraft.



NONTECHNOLOGICAL ALTERNATIVES FOR  
BALANCING AIRPORT/AIRSPACE SUPPLY  
AND DEMAND

by  
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Director of Aviation Policy and Plans

I. INTRODUCTION

Aviation users continue to place increasing demands on the infrastructure developed over the past decades to provide a safe and efficient air transportation system. The growth has been most spectacular over the past two decades, and while the role of growth is expected to be reduced in the future, nevertheless there will be growth. Capital investment in facilities and equipment and the introduction of major technological innovations have enabled, for the most part, the infrastructure to grow and keep pace with the growing demand. However, as the costs of expanding existing facilities and constructing new ones become increasingly prohibitive, more attention has been paid to alternate, low investment cost or noncapital-intensive techniques for accommodating increased demand.

These alternatives are generally of three types:

1. Alternative facilities to off-load congested airports (satellite, reliever airports);
2. Administrative (imposing maximum limits--quotas--on the number and type of operations which may use a specific airport or runway during a given time interval); and
3. Economic (charging variable landing fees, differentiated by time of day and by location; auctioning available landing and takeoff slots).

These last two measures do not physically expand capacity, but they can postpone the need for physical expansion by promoting more intensive and more economically efficient use of existing capacity.

II. SATELLITE/RELIEVER AIRPORTS--LOW CAPITAL ALTERNATIVES

The satellite airport program is aimed at reducing the mix of air carrier and general aviation aircraft in major metropolitan areas by making alternative airports more attractive for general aviation use.

The basic theme of the program is that needed short-term development for capacity and instrument training relief will be given high priority. Emphasis will be placed on projects that can be speedily implemented to

yield prompt results. Further, that priority will also be given to long run development of the total general aviation and reliever airport system in metropolitan areas and that such development is given special emphasis in the Administration's proposal for extension of the Airport and Airway Development Act. Thus, the satellite airport program is a quick response by the agency to provide improvements with follow-on efforts to be included as part of regular programming under the extended Act.

Facility installations would be funded through the FY-1980, FY-1981, and FY-1982 Facilities and Equipment (F&E) budgets. Other airport development projects would be funded with FY-1979 and FY-1980 Airport Development Aid Program (ADAP) funds. Total combined F&E and ADAP costs are estimated at \$93 million.

When completed, the four year program will have included 86 satellite airports located near 56 metropolitan areas. Proposed projects are establishment of instrument landing systems, visual approach landing systems, and construction or expansion of runways, taxiways and aprons. Establishment of full-time control towers as a part of this program are not recommended at this time. Shifts in aircraft operations will be carefully monitored, and tower service will be initiated where increases in activity warrant additional air traffic control. As part of the program, however, temporary towers will be provided at two locations to determine their impact with regard to attracting general aviation operations away from the principal air carrier airports.

Identified for the initial F&E program phase are 24 locations for establishment of an instrument landing system. Equipment will be obtained by reprogramming vacuum tube ILS replacement projects budgeted in prior years. The proposed FY-1980 budget contains \$11 million for accomplishment of the deferred ILS replacements. In FY-1981/1982, a \$23 million funding level is proposed to complete the F&E portion of the program. For ADAP funding, \$31 million in FY-1979 is recommended for projects at 49 airports. In FY-1980, a \$28 million requirement is recommended.

Major airport development projects include the allocation of \$14 million for public acquisition of four private airports and \$2 million for land purchase and initial construction of two new satellite airports at Reserve, Louisiana (to serve the New Orleans and Baton Rouge areas), and at Baytown, Texas (near Houston).

Program details are provided in Appendix A.

### III. ALTERNATIVES TO CAPITAL INVESTMENT

The alternatives to capital investment can be grouped into three categories.

Administrative Measures: Access to congested airports is restricted

through administrative fiat. The restrictions may be selectively applied to specific categories of aviation, to certain periods of the day, and to some but not all runways of an airport. The establishment of a "quota" system that limits the number of operations per hour is another form of administrative control. Airport curfews (usually imposed to deal with the nighttime noise problem) are an extreme form of quota.

Economic Measures: Airport congestion is controlled through a pricing system which imposes higher charges during periods of high demand than at other times. This category can be further subdivided into measures that place a peak-hour surcharge on aircraft movements and measures that levy the surcharge directly on air passengers.

Hybrid Measures: Access is limited by a combination of administrative and pricing alternatives. A quota system limiting hourly operations could be combined with a peak-hour surcharge or slot auction to assure that the available time slots are allocated efficiently.

#### A. ADMINISTRATIVE MEASURES

The first-order and short-term effects of administrative alternatives are straightforward and predictable. As the number of flights at an airport is reduced by imposing a quota on the number of flights scheduled or by banning specific types of operations, congestion at that airport decreases. Because the relationship between airport demand and airport delay is very nonlinear, a carefully chosen limit on operations at a severely congested airport may drastically reduce delays without a significant reduction in the number of flights. Therefore, quotas and other administrative measures have been (and continue to be) particularly attractive as a means of dealing swiftly and effectively with airside congestion.\*

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\*In 1969, the FAA in the United States imposed hourly quotas on the scheduling of operations at the three New York City airports, O'Hare International in Chicago, and Washington National. The quotas have been generally credited for strongly ameliorating the traffic congestion situation at these airports. Developments since 1969 have made it possible to eliminate the quotas at the J. F. Kennedy and Newark Airports in New York. However, the system continues to have an effect at the other three airports.

In the long term, however, the impact and benefits of purely administrative measures are less clear because they offer no assurance that economic considerations will play a role in determining who will use a demonstrably (by virtue of it being congested) valuable facility or how this facility will be developed in the future.\*\*

Once a user, for one reason or another, has been denied access to the airport, he has no way to prove that any given time slot is more valuable to him than to its present occupant. As long as the present occupant is willing to pay the fixed landing fee that the airport charges for the slot in question, everyone else is excluded. There is no opportunity to "bid up" the price of the time slot to reflect its value. Even where the time slots are periodically renegotiated, there is no way--in the absence of a pricing mechanism--of ascertaining that the right to land at any specific time will go to those who most covet that right. In fact, it is not clear that reassignment contributes anything to increasing the economic efficiency of the time slot allocations.

Administrative limitations on airport use, by keeping demand within acceptable bounds, may assure the relatively smooth operation of the facility and the lack of severe congestion into the foreseeable future. But with access to the airport restricted and with potential users unable to indicate the true value to them of future airport expansion, a false signal is conveyed to the government and the public alike. In effect, by arbitrarily constraining demand, artificial equilibrium conditions are created which, in the long run, are likely to distort the nature, quality and cost of the transportation service provided.

In summary, purely administrative measures, while effective and probably desirable in dealing with short-term congestion problems, tend to be strongly biased toward maintenance of the status quo when used over a protracted period of time. Because economic value is not fully considered in allocating time slots, current users cannot be displaced by others who may derive a higher economic value from the same time slots and the airport cannot obtain through economic mechanisms the information required to determine the need (or lack thereof) for capacity expansion or for an improved (or, for that matter, a reduced) quality of service.

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\*\*The purely administrative case is one in which rights for the use of the runways are offered and time slots are allocated either by executive fiat or through negotiations among users. In either situation, it is assumed that no explicit or implicit economic bidding for landing rights and time slots takes place.

#### B. PEAK HOUR PRICING

The use of economic incentives rather than administrative controls could alleviate the long-term allocation and development problems if those incentives could be tied to the true costs and benefits of access to the airport. However, this is not a simple task because there are both private and social costs involved.

Once the level of operations reaches the capacity of the airport, the addition of one more operation slows the flow of all operations, generating a delay for every aircraft attempting to use the facility. This additional marginal operator considers only his own delay in deciding whether or not to use the facility and fails to consider the impact on all other users. Thus the true social marginal cost deviates from and is higher than the private marginal cost.

#### C. HYBRID MEASURES

Hybrid measures use a combination of administrative and economic techniques to control demand. For example, the operational surcharge on general aviation movements during peak periods which was imposed by the Port Authority of New York and New Jersey in 1968 coupled with the "quota system" that the FAA imposed in 1969 created such a hybrid environment in the New York area. A similar example is the combination of economic charges imposed by the British Airports Authority and the quotas imposed by the United Kingdom's Civil Aviation Authority at Heathrow Airport.

#### D. PROBLEMS IN APPLYING THE THEORY

The basic arguments in favor of a time-varying structure of airport fees and some general policy guidelines (for example, fees should be proportional to the magnitude of the marginal delay costs) for setting these fees are well understood. Current pricing policies at congested airports are far from optimal from the standpoint of economic efficiency.

The next natural step should be to establish price structures that specify airport usage fees by type of operations and by time of day. Such fees would maximize the net benefits that society derives from existing airport facilities. Unfortunately, there are a number of factors that immensely complicate the determination of such a price structure, ranging from analytical difficulties to questions of policy toward specific segments of aviation. (There may be valid policy reasons not to seek economic efficiency as a primary goal.)

## 1. Determination of Equilibrium Prices

Although models exist to estimate the marginal delay costs associated with any given flight demand and capacity profiles, there is no guarantee (in fact, it is highly unlikely) that setting congestion tolls equal to the marginal delay costs under any given status quo will lead to equilibrium conditions. If a high fee equal to the current marginal delay costs were imposed on operations conducted at peak traffic hours at a specific airport, at least some of the peak hour operations would move to off-peak hours to avoid the surcharge. This would lower marginal delay costs at peak demand periods, and conversely raise marginal delay costs at off-peak periods. Runway usage fees would then have to be readjusted (lowered at peak hours and increased at off-peak hours) thus luring back some of the operations that were previously driven away. This sequence could continue ad infinitum unless some means of computing equilibrium prices exist.

In short, there is no information on the sensitivity of airport demand to changes in runway usage charges. And without this information, the effects of any specific price structure on the pattern of demand for airport operations cannot be predicted. None of the mathematical models reviewed considers demand elasticity, even at the theoretical level. They assume uniform demand which ignores the relationship between the number of operations at peak and off-peak periods and the respective levels of runway charges during these periods. This is one of the most fundamental deficiencies of the analytical work that exists to date.

## 2. Network Effects

The air transportation system requires a complex network of facilities which are often interdependent. Congestion at any one airport cannot be considered in isolation but must be analyzed with due consideration to congestion at all other airports with which this airport is linked. It is conceivable that pricing systems developed separately for two interconnected airports would cancel out each other's intended beneficial effects. Ideally, therefore, airport price structures should be determined for networks of airports rather than for each single airport in isolation, which requires a degree of complexity far beyond current analytical models and techniques.

On the other hand, one can argue that no major airport receives an overwhelming fraction of its flights from any single source and, consequently, that the interdependence is loose enough to permit examining each airport separately. Neither position can be proved or disproved at the present time.

However, the interconnection of airports cannot be dismissed so easily from an individual airline's point of view. Because of the need for high aircraft utilization, existing airline scheduling patterns are relatively insensitive to isolated changes in landing fees. Changing the arrival or departure time for a given flight at any particular airport would mean changing flight times at all other airports that the aircraft serves--not to mention the "ripple effects" on all the connecting or "feeder" flights by other aircraft which may have been set to conform with the first aircraft's schedule.

However, this is consistent with the concept of marginal cost pricing. The example implicitly states that an airline may be willing to pay a high fee for the privilege of having its aircraft land and take off at a particular time at a specific airport. Another airline or a general aviation user who does not place such a high value on the time of a flight to the same airport would not pay the high fee but would use a different facility or fly at a different time. The result would be less congestion and improved utilization at the airport in question.

However, the main point cannot be ignored: to predict an airline's response to a time-varying price structure at a particular airport, the repercussions of each possible change on the complete schedule of the airline must be considered. It is unlikely that an airport planner or airport economist can make these estimates. Therefore, knowledge about an airline's elasticity to runway fee changes will probably be uncertain for a long time to come. And, as a result, the impact of price structures on an airline's behavior can be determined in only an approximate manner rather than be estimated from specific line information.

### 3. Recovery of Facility Costs

The analysis of time-varying runway fees that would maximize social benefits did not place any minimum acceptable limits on the total revenues that airport authorities should collect from such fees. Yet such minimum acceptable limits do exist in practice because the airport must recover at least some of its maintenance, operation and construction costs. Although the degree of expected recovery varies widely not only from one country to another but also from location to location within countries (especially in the United States), there is a basic policy in developed countries that major commercial airports must be more or less self-supporting economically. This has several consequences for pricing structures. First, the minimum amount is usually substantial in absolute terms. It is, therefore, entirely possible that the airport's basic need could

exceed the amount collected under a marginal delay cost pricing policy designed to optimize the social utility of the airport. Optimality may in fact be precluded because the landing fees needed for financial support are too high and eliminate flights that would have taken place if charged only for marginal delay costs.

Second, it is very difficult to determine what the long-term costs are that must be attributed to and recovered from airside users. For instance, if one of the airport's goals is to accumulate resources for future expansion and improvements, it must know what such future changes will be and what they will cost. However, in most cases this information is unknown because future expansion plans are contingent on future airport demand (which in turn is affected by the very set of usage fees that have to be determined). In the United States this difficulty is bypassed, as a rule, by requiring recovery after the fact; after a facility has been built, its users pay fees that amortize the cost of the facility over the estimated span of its useful lifetime.

Third, the proper way of allocating facility costs among users is very controversial. Presumably, if marginal cost pricing is to be the norm, each user must pay for the additional "wear and tear" (marginal short-term costs) and the additional construction costs (marginal long-term costs) caused by his use of the airport. But, of course, it is practically impossible to really determine what these marginal costs are. The present system of computing landing fees, primarily based on aircraft weight, can be viewed as an attempt to deal in a practical way with the problem of charging for marginal facility costs.

There is, however, another interpretation of weight-based fees which, although not central to the discussion in this section, is directly related to airport congestion. Airside facilities have very high initial (i.e., construction) costs, but once the runways and taxiways are constructed, the costs caused by an additional operation at the airport are close to zero. As long as the facility is underutilized, it is to the airport's advantage to invite additional users to the facility, increasing revenues. They do this through a discriminatory price structure based on willingness or ability to pay. In this context, aircraft weight is a proxy for willingness or ability to pay: a light, general aviation aircraft whose operator cannot presumably afford a large runway fee is, in this way, charged much less than a commercial jet.

While this pricing policy may be appropriate for underutilized and uncongested airports, it is counterproductive for congested facilities. By pricing the facility according to aircraft



weight, it effectively encourages those users who are less willing to pay full costs and who, at least on the average, contribute less "transportation value" per operation to society as a whole. In fact, the only deterrent to airport use under present weight-based systems is the prospect of delay at a congested airport. Thus, a user who is able to tolerate his own delay will use the airport without considering the delay costs that he imposes on others.

#### 4. Reluctance to Change

Pricing based on marginal delay costs, in its pure form, charges each airport user with the costs that user imposes on others. An airplane landing at a busy commercial airport during a peak traffic hour could be charged \$1,000 or more, depending on the level of congestion and the mix of traffic at the airport.

Such a pricing system clearly does not consider the "ability to pay" of the user. Whereas a \$1,000 charge may be a small percentage of the total revenues of an intercontinental flight of a B-747 jet, it would exceed the total revenue of most commuter carrier flights. In other words, marginal delay cost pricing could result in a schedule of charge which may be hard (or impossible) for certain kinds of aviation or types of flights to pay. General aviation flights would feel the impact of marginal delay cost pricing most severely. Flights of regional and "third level" (commuter) carriers and, to a lesser extent, short-haul flights by trunk carriers would also be strongly affected. In short, marginal cost pricing would most likely eliminate flights for which airport fees represent a sizable percentage of the value of the flight to the aircraft operator.

Although this is the purpose of marginal cost pricing--to eliminate those to whom the value of using the airport is less than the costs they impose on others--the imposition of fees without consideration of ability to pay is such a drastic departure from prevailing practices that it may appear to be discriminatory and unfair. Those users who have relied on the traditional low cost policies and who have developed vested interests in their continuation are the major impediment to the adoption of marginal cost pricing at congested airports.

Likewise, airport administrators can hardly be expected to adopt in one single step pricing policies which are so different from the ones they have been accustomed to and with which they have had long experience. Their reluctance in this respect could be increased by apprehension regarding the exact nature of short and long-term reactions to the new policies by the various aviation interest and pressure groups. In addition, the

inability of analysts and of economic theory to determine in advance equilibrium pricing schedules and to forecast the precise effects of marginal cost pricing on airport usage raises some financial risks that could result from a departure from present practices.

To evaluate the potential economic (and political) risks and the possible benefits of peak hour pricing, actual experience and not theory is needed.

#### E. AUCTIONS, EXCHANGE MARKETS AND THEIR APPLICATION

Auctions, in one form or another, have a long history dating back to ancient times. They gained prominence in the commodity exchanges of the sixteenth century, and are still found in active use today for art sales, some commodity markets, oil lease sales, the sale of timber and mineral rights by the Federal Government, and the sale of Treasury notes. Auctions are very familiar and easy to describe, but difficult to define precisely. Perhaps the most notable feature of auctions is the passiveness of the sellers. While buyers are actively bidding for the item(s) that are for sale, the seller waits passively for the highest bid, or accepts the first bid in a Dutch auction where descending prices are announced. In most auctions, the sale is final as soon as a winner has been determined. This is a great timesaver, and perhaps the major reason for the popularity of auctions. In other types of markets, buyers and sellers engage in protracted negotiations; they may break off negotiations without reaching an agreement or contract; they may seek a better deal by trying to find other traders who will offer more (accept less); they may seek to resell items just purchased; and so on. An auction usually provides a speedy contract between a seller with an item to sell and a buyer interested in that item by allowing a large number of interested buyers to bid simultaneously for the same contract. The auction may be of the sealed-bid variety, in which case the buyers are unaware of the buyer's bids; or it may be "open," in which case all the buyers know each others' bids. In either case, once the auction is closed, the buyers must live with their mistakes. They may have paid "too much"--that is, they could have obtained the item for a lesser price. They may have failed to obtain an item by not bidding enough. In either case the auction does not provide for recontracting. Buyers can attempt to negotiate privately with other buyers in an aftermarket if one exists, but as far as the original seller is concerned, the auction contract is final.

##### 1. The Application of Auction Procedures to the Runway Slot Allocation Problem

The justification for rationing slots by price lies in the spirit of deregulation currently being espoused by the CAB. Through differential ticket pricing (in which the airlines have

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only recently been able to freely engage), the cost of the various slots can be passed through, at least in part, to the air travelers. Consequently, demand for travel at various times of day will affect, and be affected by, ticket prices; in theory, at equilibrium, an economically efficient allocation of travel facilities is a likely result.

Two types of auction procedures have received most attention. Under one, the airlines bid directly for slots or bundles of slots; under the other, they bid for the right to select a slot or bundle. Each of these procedures can be implemented within a variety of auction mechanisms.

There are also several fundamentally different ways of dealing with the results of an auction. These results can be taken as final, obligating the airlines to certain activities over a period of time. Alternatively, if the results of the auction involve minor inefficiencies which the airlines wish to rectify, they can be allowed to revise the auction outcome through a private aftermarket (which deals in "property rights" for slots), or to "back out" of certain tentative commitments (after which a secondary auction may be held), or to revise their original bids (which consequently revises the resulting allocation of slots).

A principal feature of the slot allocation problem is the fact that operations slots are used in pairs (for every landing, there is an eventual takeoff). Therefore, for example, any auction procedure under which an airline might find itself allocated an odd number of slots should be viewed as the initial part of an allocation mechanism which permits after-auction adjustment of the slot assignments.

There are a number of attractive aspects to procedures which involve the airlines in bidding for the right to select slots rather than bidding directly for the slots. Indeed, if all operations slots were distinguishable (that is, were attached to specific times), such procedures would probably be the best available. However, there are two critical disadvantages to these procedures. They are informationally complex, calling for each airline to make a large number of individual decisions in an uncertain environment. They also are highly sensitive to minor misperceptions of demand. As a result, a slot (more precisely, the right to choose this slot) in a given one-hour period may sell early in the auction for an amount substantially higher or lower than the price of an identical slot later in the auction after the total demand for such slots becomes clearer. Hence, the variance in price of identical slots may be unacceptably high.

Alternative procedures involve bidding directly for slots. Most such procedures can be viewed as dynamic-pricing mechanisms. All the slots within any given one-hour interval (of course, intervals other than one hour can also be used) are allocated simultaneously. Coordination of allocations across intervals, in order to satisfy slot-pairing requirements, is handled through subsequent adjustments to the initial within-interval allocations.

The allocations of slots within an interval can be determined by direct adjustment of prices. Assume that the expressed demand for slots exceeds supply at a per-slot price of zero. Then the price can be gradually raised; demand will decrease as the price increases. The "equilibrium" price, at which demand first equals supply, can be tentatively established, and the slots allocated accordingly. An equivalent version of the price-adjustment process has each competitor submit a price-quantity demand curve, or (under an appropriate assumption of convexity), a list of bids for an initial slot and for additional slots. The equilibrium price will be equal to the highest rejected bid.

A drawback to this approach can be seen through an example. Assume there are bids of 8, 8, 8, 7 and 6 for a supply of four slots; further assume that the first three bids are all entered

by the same airline, and the fourth and fifth bids by two other airlines. The first airline will then receive a bundle of slots of (subjective) value 24, at a cost of 18 units. However, an alternative strategy for this airline would be to misrepresent its demand, entering only two positive bids of 8 units each. Slots would now be priced as free goods (there would be no excess expressed demand), and the airline under consideration would net a gain of 16 units for the two slots purchased rather than only 6 for the three slots purchased.

An alternative pricing mechanism involves eliciting bid lists, awarding slots according to the highest bids, and charging each airline the sum of the bids (other than its own) it has caused to be rejected. An airline with  $k$  winning bids would be charged the sum of the  $k$  highest rejected bids; obviously, this cannot exceed the total amount bid by the successful bidder. In the preceding example this mechanism would charge the same amount, 6 units, to both winning airlines. The incentive for misrepresentation of demand would be eliminated.

An open adjustment period, in which the airlines are allowed to revise their bid lists in view of the across-interval slot allocations, could be permitted to facilitate resolution of the slot-pairing problem.

2. DOT Auction Proposal for Washington National Airport

The DOT is proposing a semi-annual auction procedure for National Airport with separate auctions for air carrier and commuter reservations. Reservation auctions would allow for competitive pricing of the reservations. For hours when reservations are in high demand, the price of a reservation would be high. Conversely, for hours when there is less demand for reservations, the price would drop toward zero and would become \$1.00 if there is excess supply. The specific procedure proposed by DOT consists of two elements: a "reservation auction" followed by a continuously operating "reservation exchange." The auction procedure termed the "Trading Post Auction" is described in considerable detail in a report entitled "The Allocation of Runway Slots by Auction" prepared by Econ, Inc. The proposal for air carriers is as follows (a similar procedure would be used for air taxis):

- a. Each air carrier wanting an IFR reservation would be required to submit, by January 1 and July 1 of each year, sealed bids for the reservations that it desires for the six month period beginning the following April or October. For any given hour, an air carrier could bid for one or more reservations, all at the same price or at differing prices. Each bid would be required to identify the price and specific hour for which the reservation is requested. A carrier may submit bids for as many reservations as desired in the same or different hours.
- b. Within 72 hours after the receipt deadline for initial bids, the DOT would make public the aggregate demand curve for each hour (but not the individual airline demand curves), the market price for each hour's slots, and a conditional allocation of the number of slots that they would have obtained as a result of their bids. The aggregate demand would be arrived at by adding together, at each possible price, the number of slots that each bidder desires. Either the total demand would be equal to or less than the supply of slots that are available, in which case all demands are met at a dollar price, or the demand would exceed the available supply. In the case of excess demand, the market price would be established at the highest bid price that is rejected. For example, at Washington National, the air carrier quota for any hour would initially be set at 36 slots. The highest bidders for the 36 slots would obtain them at the highest price bid but insufficient to obtain the 36th slot which would be the 37th highest price bid. Therefore, all successful bidders would pay the same price for each reservation at that hour.

- c. If the conditional allocations and prices are agreeable to all bidders, an efficient, competitive equilibrium would have been found. In this case, all reservations would be awarded based upon the initial bid prices. It would be expected, however, that many of the bidders would not be satisfied with the initial results.
- d. An air carrier wishing to submit new bids would be allowed to do so within 72 hours after the DOT announces tentative awards in accordance with proposed Section 92.135(a)(2). Only air carriers who have made a bid in the first round of bidding would be allowed to submit a bid in a subsequent round. During this additional round of bidding, a bidder would bid on any number of reservations in any hour. The sealed, secret, individual bids would be accumulated by the same procedure employed in the first round, and new conditional allocations, trading prices and total demands would be announced. This process is repeated so that instead of a one-time auction, there would be a series of auctions. Each iteration would increase the information available to the bidders, each would add to the bidder's insight into the demand pressure over all hours of the day. If, at any step, no bidder wishes to change its bid, then the process would terminate at an equilibrium solution.
- e. After any 72 hour period during which no bid revisions are received by the DOT or if the only bids received, within 72 hours since the DOT last made public the number of reservations requested, are minimally different from the last bids received, bidding would close and prices would be established. A minimum difference may be in price or in the number of bids submitted. The DOT proposes to use a minimum bid difference procedure to establish a bidding "equilibrium" that will preclude minor fluctuations in carrier bids unnecessarily extending the time it takes to accomplish the slot auction. Based on the FAA's experience with the auction simulation performed last February, the DOT proposes that a minimum difference be established at 20 percent or less. For example, if the last determined bid price was \$40 per reservation and the only newly submitted bid for that hour was \$47, the new bid would be rejected and bidding would be closed since the difference between the two bid prices ( $\$47 - \$40$  which is \$7) is less than 20 percent of the last bid price. A minimally different submission of bids would be a change in 20 percent or less of the overall awards. For example, if only 20 bids are submitted (out of a total 522 bids available in any day) for reservations, bidding would close since that is below 20 percent of the total number of slots available. In these instances, the bidders would be required to accept the slots awarded them and the obligations of payment at the final trading post prices.

- f. Alternatively, the auction would be terminated and the most recent conditional awards and prices finalized, if all participating bidders inform the DOT within 24 hours after the announcement of conditional awards that they elect to terminate the auction.
- g. The DOT would notify each successful bidder in writing of the amount of its accepted bid prices. The bidder would be required to submit to the DOT payment for one-sixth of the total amount accepted within 14 days after it has received such notification. The balance would be payable in five equal increments starting on the first day of the reservation period. Succeeding payments would be made on the first day of each month until the balance is paid.
- h. At any time between award of reservations and the end of the time period over which they were purchased, reservation owners could sell their reservation to other users through a DOT reservation exchange. Any reservation owner wishing to sell a reservation and any air carrier or air taxi wishing to purchase a reservation would notify the DOT in writing of its intention. The DOT would maintain a list of available reservations and desired reservations and bid prices, but the names of the bidders and offerors would not be disclosed until the transaction is completed. This would eliminate special deals, collusion or conspiracy among the members of any class of user. The DOT would hold available reservations open to bids for a minimum of 24 hours after notification of their availability. The DOT would sell the reservation to the highest bidder; however, the seller would not receive more for the particular slot than it paid. The excess amount over the original purchase price would be paid to the Treasury (unless authority is obtained to place the money elsewhere, as previously discussed). The seller would be absolved of any payment requirement associated with the relinquished reservation provided that the resale price received by the DOT is equal to or exceeds the seller's payment obligation. Air carrier reservations could be purchased by air carriers or scheduled air taxis while scheduled air taxi reservations could be purchased by scheduled air taxis only.



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APPENDIX A

SATELLITE AIRPORT PROGRAM  
PROPOSED FACILITIES AND PROJECTS



**SATELLITE AIRPORT PROGRAM  
PROPOSED FACILITIES AND PROJECTS  
F&E AND ADAP FUNDED**

Metropolitan Area	Satellite Airports Project	Fiscal Year						Total	
		FY-79 F&E	FY-79 ADAP	FY-80 F&E	FY-80 ADAP	FY-81 F&E	FY-81 ADAP	F&E	ADAP
Albuquerque, N.M.	West Mesa, N.M. .ILS/MALS .VASI .WAVE Runway, taxiway, apron construction				1,800	582 41 65		688	1,800
	Anchorage, AK								
	Birchwood, AK .ILS/MALS .WAVE					546 65		611	
	Atlanta (Charlie Brown), CA Runway site preparation				314				314
Atlanta, GA	Atlanta (DeKalb-Peachtree), CA Apron site preparation .Pave apron		940		1,000				1,940
	Lawrenceville, GA .ILS/MALS .SFO					500 35		535	
	Mountain, CA .SFO					35		35	
	Frederick, MD .ILS/MALS .VASI .WAVE Apron								
Baltimore, MD	Baltimore (Clen Martin), MD Apron, Pavement rehabilitation		170			53 65		664	170
					1,400				1,400

Metropolitan Area	Satellite Airports Project	Proposed Funding (\$ Thousands)					
		FY-79		FY-80		FY 81/82	
		F&E	ADAP	F&E	ADAP	F&E	Total ADAP
Birmingham, AL	Bessemer, AL					625	660
	.ILS/MALSR					35	
	.SPO						
	Caldwell, ID					675	740
Boise, ID	.ILS/MALSR					65	
	.MAVE						
	Bedford, MA						150
	.Obstruction removal, site prep.		150				
Boston, MA	Beverly, MA					250	350
	.ILS Completion (GS/MH/Rail)					40	
	.VASI					146	
	.SANDS						
Buffalo, NY	.Apron, pavement rehabilitation		350				
	Lawrence, MA						370
	.ILS Completion (GS/MH/DH/MALSR)			370			
	Horwood, MA					146	146
Charlotte, NC	.SANDS						
	Genesee, NY						389
	.ILS Completion (GS/MH/Rail)					324	900
	.MAVE					65	
Charlotte, NC	.Runway extension				900		
	Monroe, NC						630
	.ILS/MALSR					595	
	.SPO					35	

Proposed Funding (\$ Thousands)

Metropolitan Area	Satellite Airports Project	FY-79		FY-80		FY 81/82		Total	
		F&E	ADAP	F&E	ADAP	F&E	ADAP	F&E	ADAP
Chicago, IL	Aurora, IL							705	
	.ILS Completion (GS/MW/Rail)								
	.VASI					595			
	.WAVE					45			
						65			
	Gary, IN							146	
	.SANDS					146			
	Kankakee, IL							696	100
	.ILS/MALSR			640					
	.VASI					56			
	Lead		100						
	Waukegan, IL							705	500
	.ILS/MALSR					595			
	.VASI					45			
	.WAVE					65			
	Apron, taxiway		300						
	.Taxiway construction				200				
Cleveland, OH	Lorain, OH							65	200
	.WAVE					65			
	.Apron, land		200						

Metropolitan Area	Satellite Airports Project	FY-79		FY-80		FY 81/82		Total
		P&E	ADAP	P&E	ADAP	P&E	P&E	
Dallas/Fort Worth, TX	Denton, TX .Pavement rehabilitation		650					650
	McKinney, TX .ILS/MALSR .VASI					545 47	592	
	Waco, TX .Rehabilitate runway lights .Rehabilitate runway pavement		100		559			659
	Dayton (Gen), OH .ILS/MALSR .WAVE					675 65	740	205
Detroit, MI	Detroit (Willow Run), MI .Clear zone land, taxiway signs, fencing		205					
Denver, CO	Arapahoe County, CO .SANDS .Apron .Apron expansion		3,600		3,000	146	146	6,600
	Pt. Collins, CO .ILS Completion (CS/NH/Rail) .WAVE .Taxiway Construction		800	307		65	372	800
El Paso, TX	Greeley, CO .ILS/MALSR .SANDS					607 146	753	
	Jeffco, CO .Apron		800					800
	Lee Cruces, NM .ILS/MALSR .VASI .WAVE .SPO					595 44 65 35	739	



Metropolitan Area	Satellite Airports Project	Proposed Funding (\$ Thousands)				
		FY-79 P&E ADAP	FY-80 P&E ADAP	FY 81/82 P&E ADAP	Total P&E ADAP	
Eugene, OR	Corvallis, OR .ILS/MALSR .WAVE			400 65	465	
Ft. Lauderdale, FL	Ft. Lauderdale (EX), FL .ILS Completion (CS/NM/MALSR)		365		365	
Hartford/Windsor Locks, CT	Braintree, CT .ILS/MALSR .SANDS			705 146	851	
Honolulu, HI	Oahu, HI .WAVE .Land for new airport		1,000	65	65 1,000	
Houston, TX	Baytown, TX .New airport .Construct runway, taxiway, apron	500	1,000		1,500	
	Brasoria, TX .ILS/MALSR .VASI .WAVE		547	46 65	652	
	Houston (David Wayne Hooks), TX .BRITE Radar/TWL .SANDS			270 146	416	
	Lakeside, TX .Acquire airport		500		500	
Indianapolis, IN	Mt. Comfort, IN .ILS/MALSR .VASI .WAVE			595 45 65	705 3,250	
	.Construct airport (Phase III) .Runway and taxiway construction	1,250	2,000			
Jacksonville, FL	Jacksonville (Craig), FL .ILS/MALSR			595	595	

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Metropolitan Area	Satellite Airports .Project	PROPOSED FUNDING (S THOUSANDS)					
		FY-79		FY-80		FY 81/82	
		F&E	ADAP	F&E	ADAP	F&E	TOTAL F&E ADAP
Kansas City, MO	Richards-Gebaur, MO .ILS/MALSR			614		614	614
Las Vegas, NV	Wenderson, NV .ILS/MALSR			520		520	520
Little Rock, AR	Pine Bluff, AR .ILS Completion (GS/WM/Bail) .SANDS			279		146	425
Los Angeles, CA	Breckett, CA .Taxiway	630					630
	Chino, CA .ILS/MALSR .Pavement rehabilitation, lighting			741	2,000		741 2,000
Louisville, KY	Elizabethtown, KY .ILS/MALSR .SPD					635 35	670
Memphis, TN	West Memphis, AR .BRITS Radar/TWR					270	270
Miami, FL	Miami (New Tamiami), FL .ILS/MALSR .Clearing		80	465			465 80
Minneapolis, MN	Airlake, MN .ILS/MALSR .VASI .Acquire airport				2,000	745 57	802 2,000
Nashville, TN	Smyrna, TN .ILS/MALSR			419			419

Metropolitan Area	Satellite Airports Project	PROPOSED FUNDING (\$ THOUSANDS)					
		FY-79		FY-80		FY 81/82	TOTAL
		F&E	ADAP	F&E	ADAP		
New Orleans, LA/ Baton Rouge, LA	Hammond, LA .ILS/NALSR .SFO .WAVE			557		35 65	637
New York, NY	LaPlace/Reserve, LA Land - new airport				500		500
	Sidell, LA .Apron, land, new runway, taxiway		900				900
New York, NY	Brookhaven, NY .ILS/NALSR .ILS site preparation, clear some land				1,600	572	572 1,600
Oklahoma City, OK	Page, OK .ILS/NALSR .SFO .VASI					683 35 44	762
Orlando, FL	Sanford, FL .ILS/NALSR Land, clearing		96	600			600 96
Philadelphia, PA	Chester, PA .ILS/NALSR .WAVE Land, taxiway, apron expansion			457	490	65	522 490
Phoenix, AZ	Wilmington, BL Taxiway		1,400				1,400
	Chandler, AZ .ILS/NALSR			486			486
	Naam, AZ .WAVE					65	65
	Scottsdale, AZ Apron		350				350

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LaPlace/Reserve, LA  
Land - new airport

Metropolitan Area	Satellite Airports .Project	PROPOSED FUNDING (S THOUSANDS)				TOTAL	
		PT-79	PT-80	PT-81/82	FAE	ADAP	ADAP
Pittsburgh, PA	Builer, PA .ILS/MALSR .WAVE				649 65		714
	.Runway pavement rehabilitation	323					323
Portland, OR	Latrebe, PA .Apron						325
	Millsboro, OR .Runway rehabilitation	325	400				400
Providence, RI	McKinaville, OR .ILS/MALSR .WAVE .Land		490		65		555
	Providence (H. Central State), RI .ILS Completion (GS/WH/Rail) .Rehabilitate runway, construct taxiway, apron, localizer site preparation	500					500
Raleigh/Durham, NC	Providence (H. Central State), RI .ILS Completion (GS/WH/Rail) .Rehabilitate runway, construct taxiway, apron, localizer site preparation	740			225		225
	Smithfield, NC .ILS/MALSR .SFO				635 35		670
Reno, NV	Carson City, NV .ILS/MALSR .WAVE						671
	.Pavement rehabilitation	346			606 65		346
Sacramento, CA	Tuba, CA .ILS/MALSR .VASI		575				611
	St. Louis (Spirit of St. Louis), MO .Acquire airport (Phase I) .Acquire additional land, construct parallel runway	7,100	4,500		36		11,600

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		PROJECT FUNDING (\$ THOUSANDS)					
Metropolitan Area	Seattle Airports Project	FY-79		FY-80		FY 81/82	
		F&E	ADAP	F&E	ADAP	F&E	TOTAL
Salt Lake City, UT	Provo, UT . ILS/MALSS			540			540
	Salt Lake City #2, UT . Apron		400				400
	Centerville, UT . ILS/MALSS . SFO . WAVE . Runway and taxiway rehabilitation			516	35 65		616
	San Antonio (Stinson Municipal), UT . MILIT Radar/TWR					270	270
San Diego, CA	San Diego (Brown), CA . Runway and taxiway lights		121				121
	San Diego (Gillespie), CA . Taxiway construction and pavement rehabilitation				105		105
	San Diego (Montgomery), CA . ILS Completion (CS/MH/Rail) . ILS Site preparation						
San Francisco/Oakland, CA	Livermore, CA . ILS Completion (CS/MH/MALSS . WAVE						
	San Carlos, CA . Land for apron expansion						
San Jose, CA	Palo Alto, CA . Apron, taxiway						
	Tracy, CA . ILS/MALSS						
Seattle, WA	Payollup, WA . Acquire airport						

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Metropolitan Area	Satellite Airports Project	PROPOSED FUNDING (A THOUSANDS)				TOTAL	
		FY-79		FY-80		FY 81/82	
		F&E	ADAP	F&E	ADAP	F&E	ADAP
Shreveport, LA	Shreveport Bossier, LA . BRITS Radar/TWR					270	270
Spokane, WA	Coeur d'Alene, ID . ILS/MALSR . NAVE . Land		100	490		65	555 100
Tampa, FL	Lakeland, FL . ILS/MALSR . Land		120	645			645 120
Tulsa, OK	Okmulgee, OK . ILS/MALSR . SPO . NAVE			426		35 65	526
Tucson, AZ	Ryan, AZ . ILS/MALSR					741	741
Washington, D.C.	Langley, VA . Apron		205				205
	Manassas, VA . ILS/MALSR . VASI . New runway, taxiway, apron . ILS site preparation		2,960		160	595 33	628 3,120
Wichita, KS	Comstock Airport, KS . Acquire airport				640		640
	Newton, KS . ILS/MALSR . VASI . Land		75	560		33	593 75
ILS Site preparation			3,000				
TOTALS			30,854	11,390	27,623	22,955	34,335 58,477
TOTAL Program							92,812

Wichita, KS  
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